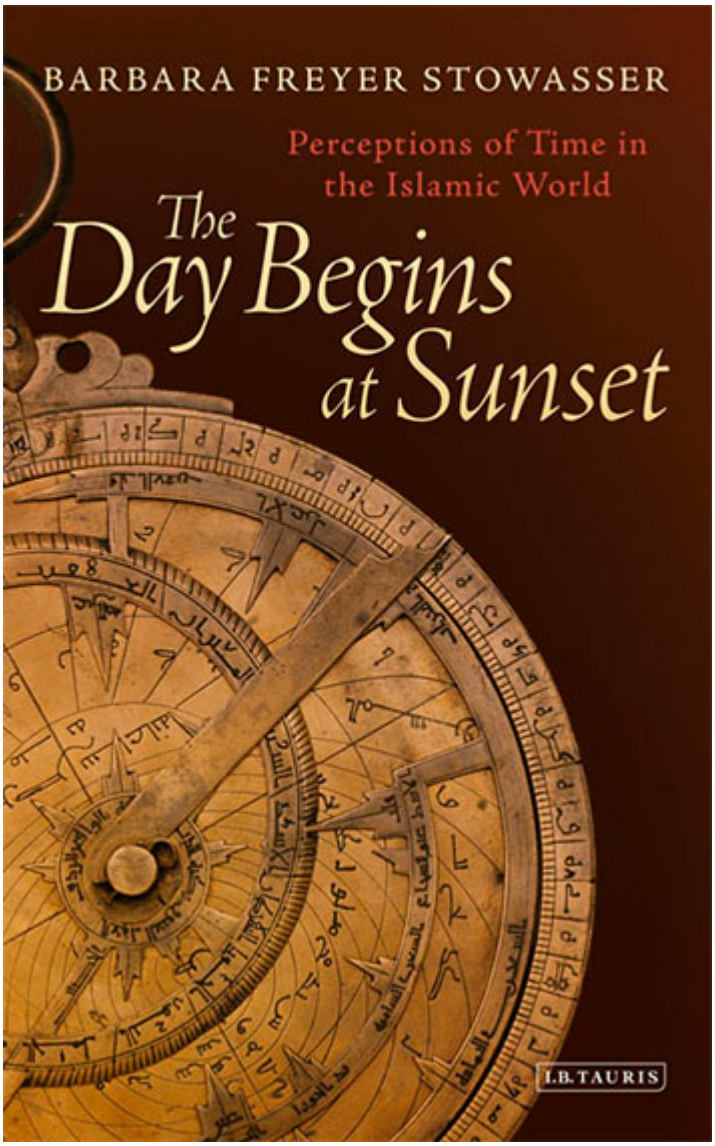
BARBARA FREYER STOWASSER
Perceptions of Time in the Islamic World
The Day Begins at Sunset
I.B. TAURIS

Barbara Freyer Stowasser was, until her death in 2012, Professor of Arabic and Islamic Studies at Georgetown University. She also held the Sultanate of Oman Chair in Arabic and Islamic Literature at the Center for Contemporary Arab Studies at Georgetown University, was a former Director of the Center, and served as President of the Middle East Studies Association (MESA) between 1998 and 1999. Her previous books include *Women in the Qur'an, Traditions and Interpretation* (1994).

‘In her enjoyable new book, Barbara Freyer Stowasser demonstrates with great clarity the centrality of time within Islamic culture – whether the time of prayers, of feast-days, of sacred months or of centennial years – and shows how understandings of chronology integrated the practices of Islam into a cosmos measured by subtle astronomical calculations and observations. The regularities of time provided a unifying structure for the whole of the Islamic realm, while the lunar year, slowly revolving through the seasons, served to distinguish Islam from its neighbours. As the author authoritatively and readably shows, a fascination with time appears in the work and thinking of Islam’s mathematicians, historians and encyclopaedists, and is therefore a topic of central interest to the student of Muslim science, history and literature.’

– Charles Burnett, Professor of the History of Islamic Influences in Europe, The Warburg Institute, University of London

‘*The Day Begins at Sunset* is a unique work of scholarly synthesis and lively narration that offers a wealth of historical, social, and religious information about timekeeping and time perceptions in the Islamic world, past and present. It also has much to say about the long coexistence in Islamic societies of serious scientific inquiry and theological interpretation before the impingement on the Islamic world of Western imperial and colonial power and its attendant cultural assumptions. The late Barbara Freyer Stowasser’s astute use of the great Muslim polymath, al-Biruni, as the principal lens through which the reader can follow her wide-ranging explorations adds a still further dimension to this learned, engaging excursion into science, religion, and history. The book is an admirable final chapter to a perceptive scholar’s corpus of work.’

– William A. Graham, Murray A. Albertson Professor of Middle Eastern Studies and University Distinguished Service Professor, Harvard University

‘Well presented, well informed and well researched, the book is readable and interesting, and I will recommend it to my students. *The Day Begins at Sunset* engagingly treats a subject for which there is little accessible published material.’

– Robert Hoyland, Professor of Islamic History, University of Oxford

‘Throughout human history people have devised ways of measuring the passage of time. *The Day Begins at Sunset* focuses upon solutions adopted in the Islamic world, but a reader will be introduced to the earlier Sumerian–Babylonian, Roman, Jewish, and Christian calendrical systems as well. The author has placed at the centre of her book the remarkable writings of al-Biruni, an early 11th-century polymath, the uncontested medieval authority on time and timekeeping, and a thoughtful and influential voice on the relationship between science and religion. By structuring her volume in this way, the late Professor Stowasser was able to transform a complex topic into an engaging and highly readable book – one that provides an excellent, reliable introduction to Islamic science in general as well as early Islamic perceptions of time. *The Day Begins at Sunset* is highly recommended as a starting point for anyone wanting a non-technical guide to pre-modern Islamic science and its relationship to religion.’

– Emilie Savage-Smith, FBA, Professor of the History of Islamic Science, University of Oxford

‘Sadly, this is Barbara Freyer Stowasser’s last insightful study on Muslim civilisation. Here, the subject matter is Time. The Muslim vision of time is God-centred and based on the Qur'an. Time moves in the sun’s rhythm measuring night and day, while from the moon’s phases months and years are calculated: all signs of divine power and providence. While measurement required scientific knowledge, scriptural exegesis necessitated religious knowledge. Stowasser’s central point is that many Muslim theologians and scientists viewed both sources as mutually independent forms of intellectual enterprise, thereby preserving the truth and validity of each in proclaiming the divine secrets of God’s creation. The crucial chapters of her study are devoted to a stimulating examination of the works of Abu al-Rayhan al-Biruni (d. ca. 1050), mathematician and ethnographer extraordinaire, and his description of the calendars of the ancients including those of the Greeks, Persians, Christians and Jews.’

– David Waines, Professor Emeritus of Islamic Studies, Lancaster University

The Day Begins at Sunset

Perceptions of Time in the Islamic World

BARBARA FREYER STOWASSER

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To my sons, Andy and Mike; their wives, Teresa and Jill; my grandchildren, Franci, Margaret, Leanna, and David; my sisters, Ulli Hauck and Brigitte Schauenburg; my colleagues at Georgetown University; and all of my students over these many years.

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PART I

HISTORY, RELIGION, POLITICS AND TIME

CHAPTER 1

CALENDARS: AN INTRODUCTION

Calendars are Cultural Artefacts

In the liturgical calendar of the Roman Catholic Church, the interval between Corpus Christi and Advent is called ‘Ordinary Time’. On a recent Sunday in late June, the parochial vicar Father Joseph Kelly, SJ, of St. Malachy's Church in Manhattan, New York, used his homily at the Actor's Chapel and the day's newsletter to reflect on the date:

> For quite a few Sundays now, we have had major feasts. Easter, Pentecost, Trinity Sunday, and last week, Corpus Christi. Now we move into that period most dreadfully designated as ‘Ordinary Time’. (I often wonder what clerical bureaucrat thought that one up?) Quite frankly I don't know what it means, because time, Ordinary or otherwise, is a most precious gift of God which makes me think that this might be a good Sunday to look at the simple word – time. What words do we use when we talk of ‘time’? We ‘bide’ our time, some unfortunates ‘do’ time, others of us ‘put in’ time, we look back nostalgically at ‘old’ times, and perhaps most awful of all we ‘kill’ time, while our military people ‘mark’ time. And yet what a precious gift it is. It slips through our fingers so quickly, and the less you have, the quicker it slips. None of us know our ‘allotted’ time.

The vicar was addressing one of the several essential functions of calendars: the sacralization of time. Calendars are cultural constructs in which religion and science collaborate. They are also usually manipulated by political interests, either initially or later. To set up and then maintain a calendar, especially if it is complex, requires a combination of expertise and executive authority. In their historical variety, systems of time management are therefore key to the study of civilizations. At the same time, calendars can embody processes of cross-cultural borrowing that yield patterns of globalizations both old and new. Multiculturalism is four-dimensional, because cultures use the fourth – temporal – dimension to link points on the three-dimensional globe in various ways.

The cycles of the sun, moon and stars exist whether or not our planet's human inhabitants feel challenged to appropriate them to measure time. But if they did, as was usually the case, their societies' structuring of observable time was and is based on astronomy: the succession of days and nights punctuated by the waxing and waning of the moon, the movement of the sun and the rhythm of the seasons or a combination of the two. The rest is manipulation, the elaboration of mental constructs that are abstract things. There is enormous historical and contextual variation among calendars, which may be less surprising than the similarities that can also exist among calendar systems of vastly disparate civilizations (such as the fact that the Mayan, Aztec, Sumerian, Babylonian, Egyptian, Indian and Chinese calendars were all at one time or another rooted in a sexagesimal system of numbers). Clearly, some calendric parallelisms and similarities among civilizations have been and are coincidental, while others suggest the existence of often long-range but frequently obscure cultural influences.

The 12-month year with its seven-day weeks that now underlies the Jewish, Christian and Islamic calendars is one of the oldest, in that the ancient Mesopotamians also had it. Their year was lunisolar; to have both true lunar months and the true tropical year of the seasons worked through the device of intercalation of a set number of extra months according to an eight-year or, better yet, 19-year cycle of 12 ‘common’ years and seven ‘leap’ years, determined by sophisticated astronomical observation and mathematical calculation. Regardless of how long the period that cultures defined as their calendar year, the manner in which they subdivided it has also varied widely, with weeks that

consisted of four or eight or 13 or 16 days; ten days made a week in ancient Egypt and then again in the Calendar of Reason and Liberty of postevolutionary Republican France, and 19 days make a month in the Baha'i calendar. Sometimes an autocratic ruler, even though he continues with the established calendar of his region, may merely rename all the months of the year to honour his own person and background, life, priorities and family, as did the Turkmen leader Saparmurat Niyazov (who died of a heart attack in December 2006), who decreed that his honorific title 'Turkmenbashi' (Leader of All the Turkmen) would henceforth be the official name of Turkmenistan's highest mountain and also of the month of January, while 'Gurbansoltan Eje' (his mother's name) became the name of the month of June.

Time is always structured for a purpose, and usually more than one. Historically, these have been a mixture of the economic, the political and, in a broader sense, the ideological. The latter prominently involves religion; most calendars appear to have grown from some religious impulse, while a few of the modern secular ones (like the postrevolutionary French calendar) were designed in the combative mode of antireligion and usually had a short shelf life. (The French revolutionary calendar, introduced in 1793, had its epoch, or starting point, fixed at 22 September 1792, the day of the proclamation of the republic and date of the autumnal equinox; 13 years later, it was all over, when Napoleon reinstituted the Gregorian calendar, from 1 January 1806.)

When Julius Caesar devised the Julian calendar in 46–45 BCE (before the Christian Era) by replacing the old and patchy, semilunar Roman calendar with the solar one, he introduced 12 months of varying length (of which the seventh was thereafter named 'Julius' in Caesar's honour in 44 BCE and the eighth 'Augustus' in honour of Octavian [Augustus] in 8 BCE). But Caesar preserved the old irregular Roman subdivisions of the months (*kalends*, *nones* and *ides*) that held political, commercial and especially religious significance for traditional Roman culture, even though the seven-day planetary week had become popular. That seven-day week (possibly borrowed from the Jewish practise of seven 'numbered' days) did not achieve official status until Emperor Constantine, newly emerged patron of the Christian religion, in or around 321 CE (Christian Era) designated Sunday the first day of the week and day of the Lord; undoubtedly, this decision was meant to symbolize Christianity's victory over its longtime rival, Mithraism, cult of the sun god Mithra, whose feast day was Sunday, but it also derived from the emperor's perception of the seven-day week as a monotheistic, biblical device.

In many solar and lunisolar calendars, the beginning of the year was fixed at equinox or solstice. In ancient Egypt, the year began around the summer solstice with the heliacal rising (first sunrise appearance) of the star named Serpet or Sirius, the Dog Star, that heralded the flooding of the Nile. The Babylonians began their new year in mid-March at the vernal equinox; this tradition has survived in the Jewish and Iranian calendars. The Athenian year began with the new moon immediately after the summer solstice; on Delos it was the winter solstice, most city-states had their own calendars and even in a single city calendrical practise was not always uniform. (In his satirical comedy *The Clouds*, Aristophanes made merciless fun of Athenian calendar practises.) Roman calendars of the monarchy began with the spring equinox, but with the rise of the republic in the first century BCE, the Romans adopted 1 January for their New Year's, because 1 January was when their consuls took office. Since the church wished to dissociate itself from pre-Christian practises, it preferred the liturgical year as the determining subtext on when a calendar year would begin. In Latin Christianity, Advent, Christmas, the Annunciation or Easter (the latter being especially inconvenient since local calculations of the correct date of Easter varied considerably) all served as New Year's dates in various countries of the Christian West until the eighteenth century – that is, well beyond 1582, when Pope Gregory XIII established the Gregorian calendar with a New Year's date of 1 January and a new canon for the calculation of Easter.

The Julian calendar year had been a trifle too long, which had caused retrogression of the spring equinox by about three days every 400 years and played havoc with the calculation of Easter (whose date depends on both the lunar cycle and the vernal equinox). By the sixteenth century, the vernal equinox had worked its way from March 21 to March 11. The shift from the old Julian to the new Gregorian system therefore meant the elimination of ten days (5–14 October or 22–31 December 1582) from the calendars of the European nations who went Gregorian. But because it had been enjoined by a pope known as a fervent supporter of the Counter-Reformation, and because they generally considered popes the Antichrist, most Protestant states rejected the Gregorian calendar until the eighteenth and nineteenth centuries. To catapult from the Julian into the Gregorian system at that later date required the elimination of 11, eventually 12, days from the calendar. In England, the shift

occurred in September 1752 and reportedly led to widespread riots. The founding fathers of the United States were typically born in a Julian calendar year and buried in a Gregorian one. Japan went Gregorian in 1873 and Egypt in 1875. Russia changed over to the Gregorian calendar after the revolution, when the difference between the calendars had grown to 13 days. The Eastern Church still celebrates Easter by the Julian canon in a somewhat modified form; as their calculation of the Paschal full moon is five days later than the astronomical full moon, their Easter sometimes coincides with the Western (Roman) date, but is often one, four or five weeks later.

Chronographies are Sociopolitical Constructs

Chronographies are likewise culture-specific social constructs. Throughout history, local schemes (such as regnal years, or even counting the years by a series of Olympiads) have predominated, but literate cultures on the whole tended to produce larger dating systems. The question of whether these were also always universalist in intent is difficult to answer. Here our clues may lie in their symbolic parameters, especially the retrospective significance of the 'starting date'. Calendar reforms can likewise shed light on how a culture, and an age, perceived itself in relation to a universal order.

During the last years of the republic, in Caesar's time, the Romans elaborated a new chronology that began with the foundation of Rome (AUC, *Ab Urbe Condita*), a mythical event in the far distant past that was fixed in 753 BCE; in 247 CE, during the height of their empire's territorial expansion. The Romans minted coins to commemorate the 1,000th anniversary of their Eternal City. A symbol of successful empire building, this chronography to the Romans was clearly a matter of universal import; at the time of Rome's 1,000th anniversary, the empire was also persecuting its monotheistic minorities.

The Jewish and early Christian chronographies were thus developed by communities experiencing not political victory but political persecution. During the early centuries CE, of the Common Era, and against Rome's new imperial calendar, Judaism and Christianity more or less simultaneously adopted chronologies that started with the creation of the world as they estimated it (AM, *Annus Mundi*) to symbolize the antiquity and universal relevance of the Jewish–Christian tradition.

One of the rabbinic creators of the Jewish dating system, Rabbi Ben Halafta, during the second century CE of the Common Era, calculated the age of the world by adding up the life spans of patriarchs and kings and other historical periods listed in the genealogies and histories of the Bible and estimated the number of years from the Creation described in Genesis to an historical event whose date was known: the destruction of the Second Temple in Jerusalem by the Romans. By these calculations he arrived at the equivalent of 3761 BCE for the creation of Adam. There were also other Jewish calculations that produced different starting dates, and in any case this Jewish AM era was not generally applied until much later. The Jewish calendar (one of the most complex in existence) is discussed in what follows. Here it will suffice to say that its AM universalist chronography was or became an institution that would provide the Jewish people with a civilizational identity over large geographical distances.

Time and End-Time in Christian Calendar Counting

Eschatological doctrine was highly developed in Zoroastrianism, and its teachings had profound influence on the eschatologies of Judaism, Christianity and Islam. This included the fact that round numbers and sacred numbers in the calendars of the three civilizations could arouse or strengthen their apocalyptic impulse. In the eschatological context, chronography and calendars can acquire symbolic meaning – indeed, cosmic significance. Millennialism, or millenarianism, is the belief in the kingdom of holiness, peace, justice and plenty that the Messiah will establish on earth before the Last Judgement. Although the term *millennium* implies a 1,000-year kingdom, its duration – which is predicted in a variety of time frames, especially in Jewish and Islamic sources – is of secondary importance; what matters is that, initiated by signs portending the cataclysmic end of ordinary time and after a preliminary period of purging and transformation, human society reaches its final state on earth when all conflicts are resolved and all injustices removed. The books of Ezra, 2 Isaiah, Jeremiah, Ezekiel, Daniel, Joel and Zecheriah all speak to the rich Jewish tradition of apocalyptic visions. All Jewish eschatological thought is millenarian, centred on the expectation of the long-awaited arrival of

the Messiah, David, or from the House of David, who defeats Belial (or Beliar), the lying seducer who calls to worship false gods, the Antichrist, the deceiver and Gog and Magog (Deut. 13; Ezek. 38:1–39:29). The Messiah redeems Zion and builds the new Temple (2 Isa. 65:17, 25; Ezek. 33–9, 43; Dan. 7–12; Joel 3; Zech. 9:8–15, 14). Political persecution, economic deprivation, alienation and other forms of despair can sharpen the urgency of apocalyptic anticipation, and some of the writers of these biblical texts did indeed live in truly terrible times: Daniel during the persecution of the Jews by Antiochus Epiphanes and Ezra after the destruction of the Temple.

In the Christian faith, the messianic promise was fulfilled with God's Incarnation in the person of Jesus Christ. Thus, Christians now await Christ's Second Coming, the Parousia (Matt. 24:1; Cor. 15), when the Archangel Michael comes down from heaven, binds Satan, casts him in a bottomless pit and shuts and seals it, after which Christ and the saints will reign the earth for 1,000 years (Rev. 20:1–6). *Chiliasm* is another term for the belief that Christ's kingdom, the 'first resurrection' of the elect, will last for 1,000 years before the final consummation. Then God's enemies – the antichrists with their false messages (1 John 2:18–22; 2 John 7), the blasphemous Beast (Rev. 13), Satan loosed out of his prison and Gog and Magog – will be punished forever (Rev. 7:9–17, 14:13–16, 20:7–10), while the blessed dwell eternally in God's city, the new Jerusalem (Rev. 13).

The early Christian AM calendar differed from the Jewish in that it placed the world's creation at a considerably earlier date, 5,500 years before the Incarnation. The second and third-century Christians who designed it thus posited themselves into the second half of the sixth millennium of the age of the world. With the approaching end of the sixth millennium AM (which was to mark the end of the world in apocalyptic tradition), some among the Latin church fathers reformed the calendar downward by three centuries, changing the date of creation from 5,500 to 5,199 years before the Incarnation. Another 300 years later, when the end of the millennium was once again approaching, the 5199 *Annus Mundi* starting date had again ceased to be a comfortable date for those Christian faithful who were literate in matters calendric as well as apocalyptic, and also for their rulers.

Thus, it was the Carolingians, patrons of the chronographic work of the Venerable Bede (d. 732 or 735 CE), who in 741 CE officially abandoned the Christian AM system in favour of the Christian *Annus Domini* era that had been developed two centuries earlier, in 525 CE, by Dionysius Exiguus, Dennis the Little, a sixth-century abbot from Scythia (now Moldava) whose nickname derived from his self-demeaning manner. Dennis, in his writings about how to improve the calculation of the date of Easter in the liturgical year, had also invented a new era: his 'Year One of the Lord' (*Annus Domini Unus*) began on 1 January of the year that followed the year of the birth of Christ.

The epoch (the fixed point that starts the era) thus is the birth of Christ. Dates before the epoch can still be specified. In the Christian calendar, all dates before AD 1/1/1 (now CE) are marked BC (now BCE), so the year before AD 1 is 1 BC; there is no year zero. According to E. G. Richards' work *Mapping Time*, astronomers for the sake of convenience have used the alternative convention of referring to 1 BC as the year 0, 2 BC as the year -1 and so forth; 0 or negative years are thus BC, and positive years are AD.

The Coptic Church numbered their years from the accession of Emperor Diocletian, renowned for his persecution of Christians. Their year 1 of the Era of Martyrs corresponds to the Julian calendar date of 29 August 284 CE. Dennis invented his new era so that he need not associate Christianity with the era of Diocletian, which had been used in the Alexandrian system for calculating Easter. But when Dennis reworked previous Alexandrine Easter tables, he probably miscalculated and thus placed the birth of Christ at a date that scholars believe is most likely three years too late, or perhaps seven years too early. But to this day, the very place of Christmas in a chronologically universal salvation history is celebrated in the 'Proclamation of the Birth of Christ' from the *Roman Martyrology for Christmas Mass* whose text is read at Christmas services both Catholic and Protestant as follows:

> The twenty-fifth day of December. In the five thousand one hundred and ninety-ninth year of the creation of the world from the time when God in the beginning created the heavens and the earth; the two thousand nine hundred and fifty-seventh year after the flood; the two thousand and fifteenth year from the birth of Abraham; the one thousand five hundred and tenth year from Moses and the going forth of the people of Israel from Egypt; the one thousand and thirty-second year from David's being anointed king; in the sixty-fifth week according to the prophecy of Daniel; in the one hundred and ninety-fourth Olympiad; the seven hundred and fifty-second year from the foundation of the city of Rome; the forty-

> second year of the reign of Octavian Augustus; the whole world being at peace in the sixth age of the world, Jesus Christ the eternal God and Son of the eternal Father, desiring to sanctify the world by his most merciful coming, being conceived by the Holy Spirit, and nine months having passed since his conception, was born in Bethlehem of Judea of the Virgin Mary, being made flesh.

The Carolingians' decision in 741 CE to shift from the old *Annus Mundi* (AM) chronology to sixth-century Abbott Dennis' 'new' AD system retargeted the end of the (newly calculated) first millennium to AD 999/1000, then safely two and a half centuries away. These now curious, because largely unexplained patristic and medieval West European calendar revisions have been read by David Landes and others as evidence of an ongoing oral, popular and largely underground millenarian tradition based on the early Christian notion of the 'millennial week' that combined Genesis 1 ('the six days of creation') with Psalm 90:4 ('a thousand years are as a day passed in the sight of the Lord') and that dated the Second Coming at the start of the seventh millennium.

Among medievalists, the significance of the year AD 1000 for Christians East and West is a highly contested item. One school of historians downplays the credibility of a mob scene at the Church of the Holy Sepulchre in Jerusalem on New Year's Eve AD 999 that an eyewitness, the Burgundian monk Radulfus (Raoul) Glaber, described in his *Chronicle*. Christendom, after all, was then celebrating New Year's on different days – Christmas Day in Rome, Easter in France, 1 January in Spain and 9 July in Armenia – and endowing that date with such terror, anticipation and hope was the work of revisionist nineteenth-century Romanticism. The other school condemns this positivist assessment – that '1000 was a year like any other' – as capstone or 20/20-hindsight historiography where credence is placed only in the retrospective narrative of official, hence politically correct, medieval sources. Not only were AD 1000 (anniversary of Jesus's birth) and AD 1033 (anniversary of the Crucifixion) years of intense popular (and therefore largely unrecorded) apocalyptic expectation, but they also defined a millennial generation of newly activist Christians who initiated heresies and reform movements, embarked on large-scale pilgrimages (and, eventually, Crusades) to Jerusalem and organized peace assemblies and communes, all (according to this second school of thought) indicative of the spiritual renewal that the advent of the millennium had brought.

As already mentioned, Judaism and Islam have similar traditions that interpret a calendar's round numbers in the context of an apocalyptic millenarianism. Judaism and Islam also share the fact that their respective organized establishments, both political and religious, have – like the Christian – always considered apocalyptic millenarianism extremely dangerous. To the evangelists of the early Christian Church, the Jewish revolts against Rome in 70 and 135 CE were examples of it that spooked them into condemning the whole concept as heresy. Jesus had indeed told his disciples to expect signs within their generation, but had also said that the day and hour were known only to God (Matt. 24:36; Mark 13:32; Acts/Luke 1:7). Peter wrote that 'the day of the Lord will come as a thief in the night' (2 Pet. 3:10). The early architects of the institutionalized Christian Church, Paul (first century) and Augustine (late fourth or early fifth century) emphasized that the eschatological process had already begun with Christ's Incarnation; his Second Coming, whenever it occurred, would bring it to an end, and in the meantime the church acted as his representative on earth. Following Augustine's lead, the Council of Ephesus in 431 CE denounced the eschatological interpretation of the millennium and all 'Jewish' apocalypses as error and fantasy. The tradition however, has survived and flourished, at first mostly outside the Christian Church (while it was unified) and later mainly within some of its newer branches. Apocalyptic prophesies and expectations have been powerful devices in the imagination of those among the religious for whom beliefs act as facts in society, history and politics. In addition, the idiom of religion is adaptable to secular mind frames and secular millennialisms, and both religious and secular millennialisms have been open to exploitation by political systems for alternate purposes.

CHAPTER 2

THE ISLAMIC CALENDAR

The Rise of the Islamic Calendar

Unlike the Jewish and the early Christian, the Islamic calendar was designed and instituted by an empire-building culture. Its chronography is said to have been instituted in or around 642 CE by the second caliph, Umar ibn al-Khattab (d. 644). Ten years earlier, during the Farewell Pilgrimage and shortly before he died in 632 CE, the prophet Muhammad had abolished the lunisolar calendar of pre-Islamic Arabia (which started and ended in the autumn) and decreed the new lunar year. No specific revelation had instructed him to do so, but Qur'an 9:36–7, revealed a year or two before, had entailed censorship of the pagan method of intercalation that periodically wedged an additional month between the two sacred months of Dhu al-Hijja and al-Muharram, interrupted the sequence of the four sacred spring months (Dhu al-Qa'da, Dhu al-Hijja, al-Muharram and Rajab; see Sura 9:36) of the lunisolar year, and thereby played havoc with the Trucial laws of Arabian tradition. In Sura 9, revealed in 630 or 631 CE, the believers are told in verse 36 that:

> the number of months in the sight of God is twelve months by God's Book [decree] on the day He created the heavens and the earth. Of them four are sacred. That is the correct religious practise, so do not wrong yourselves in them and fight the pagans altogether, as they fight you altogether. And know that God is with those who restrain themselves.

The following verse, 9:37, outlaws the pagan practise of intercalation as follows:

> Know that intercalation is an addition to disbelief [or: is but an increase in unbelief]. Those who disbelieve are thereby led to error, making it lawful in one year and forbidden in another, in order to adjust the number [of months] made sacred [forbidden] by God, and make the sacred [forbidden] ones permissible [lawful]. The evil of their course seems pleasing to them. But God gives no guidance to those who disbelieve.

Clearly, this Qur'anic legislation addressed a situation where someone (perhaps from among the Quraysh or someone else controlling this major Arabian shrine and market fair) had usurped and then manipulated the right to ‘adjust’ the lunisolar calendar of pre-Islamic Mecca by way of intercalation. Some interpreters have proposed that the intercalation issue signified at least in part the Qur'anic sanction to sever the rules of Muslim warfare from the rules of pagan warfare and its concomitant tradition of Trucial months. Others have speculated that the end of intercalation (which initiated the beginning of a strictly lunar Islamic calendar) was intended to remove Islam's pilgrimage celebrations from the spring season where they had frequently coincided with Passover and Easter. In any case, the Muslim community, at the Prophet's directive, relinquished the lunisolar calendar and adopted a strictly lunar one in 632 CE, shortly before the Prophet's death.

The ten (lunisolar) years of Muhammad's life in Medina and the ten (lunar) years following his death in 632 were not numbered but carried names of memorable ritual and/or political events. It was only in 642, 20 (solar) years after the Hijra – the Prophet's flight from Mecca to Medina – that the caliph Umar fully initiated the Islamic chronographic system by taking 16 July of the year 622 (Julian calendar) as the starting date of the Islamic era (in Latin, AH, *Annus Hegirae Unus*). Some say that the new calendar was instituted in 636 or 637 CE. In any case, the chosen starting date of year 1 of 16 July 622 corresponded neither to the prophet Muhammad's departure from Mecca nor to his arrival in Medina (both of which had occurred in September 622) but represented a calculation by a caliph-

assigned calendar committee on how the new lunar calendar could retrospectively be fitted most seamlessly with the old lunisolar one. Modern historians of astronomy such as David King point out that the choice of this date was based on observation and popular reckoning, not astronomical calculation. Friday, 16 July 622, was the evening of 'first visibility' of the lunar crescent that marked the beginning of the pagan Arab year in which the Prophet had migrated from Mecca to Medina; according to astronomical calculation, the epoch (date from which the beginning of year 1 of the Hijra calendar is counted) was in fact the preceding day, Thursday, 15 July 622, which was the day of 'the true moon, the conjunction', but at which time the crescent was invisible. This tells us that at the time of the institution of the new Islamic calendar under Umar's caliphate, astronomical knowledge in Arabia was still observation-based rather than theoretical and was thus in a way parochial.

But in 642, under Umar, the great multifront wars of Arab Islamic expansion were also already in full swing. Islam was becoming a world power, and the new chronology affirmed the self-identity of the Islamic commonwealth as much as it obliterated access to the old Arabian tribal past. In its global and universalist thrust, the new Islamic calendar was a fitting symbol for the culture and the age that produced it. The age of science followed soon after, with the beginnings of deep acculturation processes that nourished Islamic civilization with the knowledge and resources of an older world.

The Science Factor and the Islamic Calendar

Time measurement holds a prominent place among the rules and regulations of Muslim rituals. Its tasks can be achieved without knowledge of astronomy and without sophisticated technology. But the very importance of predicting and defining lunar cycles and daily prayer times (and also calculating the correct local *qibla,* prayer direction toward the Ka'ba in Mecca) made astronomy an Islamic science of practical merit. The sophistication of astronomical and mathematical knowledge and discovery, even at an early date in Islamic history, derived in part from this tight linkage with religion that would often ensure funding for scientific projects from both princely and private charitable resources endowed for the moral and spiritual well-being of the community. It also derived from the fact that the Islamic realm, by way of conquest and expansion, fell heir to several much older civilizations that had long traditions of scholarship in the theoretical and applied sciences. Among the reasons to embrace this ancient and foreign legacy, the religious motive was operative for many or most Muslim scientists, meaning that their motivation had deeper roots than mere practical utility. Astronomers saw their studies as a way of understanding God's plan for the world and of glorifying Him by exalting His works. For others, the main benefit of astronomical knowledge may have been the skills it lent to the practising astrologer. Perhaps the most constant and important impulse for the study of astronomy or any other science in the Islamic world at that time, however, was the ideal of science for its own sake. From an early date, Arabic Islamic culture was profoundly and solidly a scientific culture, and the translation movement of Indian, Persian and Hellenistic sources into Arabic, to be presented in what follows, was a consequence rather than the source of this interest.

This book deals with some of the ways in which Islam and Muslims have conceptualized, ordered, measured, calculated and otherwise structured the flow of observable time. Some of our sources are taken from the literature of religion and law; others are the works of cultural historians and scientists. The cultural climate that they convey is one of symbiosis of religion and science. A critical part in these events was played by the movement of translation of texts of high learning and culture from Greek and Syriac, Indian (Sanskrit) and Persian (Pahlavi) into Arabic that began during the first century after the rise of Islam. Pursued at first in the existing capitals of classical learning, such as Jundishapur (south west Iran), Damascus (Syria) and Alexandria (Egypt), and later also in newly created Islamic urban centres like Baghdad (Iraq) and Cairo (Egypt), the translation movement eventually Arabicized centuries' and even millennia's worth of major works in natural science, philosophy, literature and even religion. In certain cases, this linguistic transformation was so fundamental that it produced a conceptual transformation of entire disciplines. The translating scientists undoubtedly kept to the spirit of the originals, but when they searched for suitable Arabic equivalents for a Greek or Syriac, Persian or Sanskrit term, they were inevitably forced to clarify concepts that were vague in the original. While the lexicographers established an inventory of the Arabic language, the scientists provided an inventory of knowledge. Identification and verification necessitated experimentation, observation, calculation, measurement and accurate description of natural phenomena. It produced the objective scientific attitude that distinguished the Islamic scientists even from their sources; in this new paradigm, science ceased to be linked with

contemplation or metaphysical speculation and developed along experimental and operational lines. In what follows, we will 'embody' this story by telling it through the life of one of medieval Islam's great astronomers and mathematicians, Abu al-Rayhan al-Biruni, who also had a special interest in 'determining the coordinates of times and places' in his own culture and the cultures of others. His example holds instruction on both the appropriation and the critique of foreign scientific achievements and their enhancement and florescence in an Islamic setting; on the intricate relationship between scientific knowledge and religiosity, Hindu and Hellenistic paganism and Muslim monotheism; and on how Muslim mathematicians and astronomers discovered the laws of the universe and the meaning of scripture, all in the premodern, precolonialist Islamic world.

The Islamic Calendar and Islamic Cultural Unity

The 'largest' time system of all, Islamic chronography, has received the least attention in the literature on Islam and time. Islam's calendar of years was established swiftly and early, and quickly became a historical fact, yet it is most remarkable and significant that this should have been so. When soon after the Prophet's death the Islamic realm expanded to include all of the Persian Empire, most of the provinces of the Byzantine Empire north and south of the Mediterranean Sea and most of the Iberian Peninsula, a new Islam-focused civilization took shape in these vast territories that privileged Islamic religion and Arabic language over older, indigenous cultural allegiances and linguistic heritages.

One of the fundamental institutions that aided this new civilization in constructing its cultural unity over unprecedented distances was the ritual obligation for every free adult Muslim, if able, to perform at least once in his or her lifetime the pilgrimage to the Ka'ba, God's House in Mecca (Sura 3:97). This religion-mandated mobility created and facilitated the maintenance of regular contact between widely separated Muslim populations and fostered a sense of civilizational identity over large geographical distances.

Another institution that held the Islamic world together was the Islamic calendar. One of its greatest advantages may have been that it was so low maintenance. By adopting a strictly lunar system, the beginnings (and thereby the ends) of the 12 months of the year, and therefore of the year as a whole, could be determined empirically, anywhere, by way of sighting of the new moon that signalled a new month's beginning. This produced months of uneven length in the year. At present, the moon revolves around the earth in about 27 1/3 days (27 days, 7 hours, 43 minutes and 11.5 seconds of mean solar time) (the 'sidereal month'), but because the earth is itself in motion, this revolution (the 'synodic month') takes approximately 29 1/2 days (29 days, 12 hours, 44 minutes, 2.8 seconds), which is the average period of recurrence of the phases of the moon, as from new moon to new moon – a far cry from a round number. Because of the fractions, this system eventually required intercalation to fix the length of the months in the *civil* calendar, but the *religious* calendar has remained dependent on the first sighting of the lunar crescent (as discussed below). In and around year 2000 CE, the 12-month lunar year measures approximately 354.3672 days.

By opting to go lunar, the official Islamic calendar was, of course, decoupled from the seasons. This created administrative and, especially, taxation problems from the start that Islamic states sought to resolve by adopting some sort of secondary calendar, varying from region to region, that was typically of pre-Islamic or otherwise extra-Islamic origin. The great benefit of the systemic simplicity of the Islamic lunar calendar, however – no matter how inherently fluid – was that it eliminated the need for complicated rules of calendric adjustments, as was the case with all solar calendars.

The earth itself performs a complete revolution once in 24 hours and at the same time revolves around the sun in slightly less than 365 1/4 (365.2422) days. Even though in the geocentric model embraced by Aristotle and Ptolemy, and adopted by the Islamic scientists, it was the sun that revolved around the earth, the period of the earth's annual orbit around the sun is equal to the period of the sun's apparent annual orbit around the earth. In other words, this difference in conceptual models did not change the mathematics of the case. Islamic scientists of al-Biruni's generation knew full well that at their time (around the year 1000 CE), the mean length of the solar or tropical year was 365 days, 5 hours, 48 minutes and some seconds (the Syrian astronomer al-Battani [d. 929] had calculated it at 24 seconds, while at his time it was 50 seconds); in either case, it was another far cry from a round number. Since the solar calendar was by nature tied to the seasons, meaning that its months were not permitted to float, it took both scientific and political muscle to establish and, especially, maintain a solar calendar through constant adjustments; this often led to the adaptation of different calendars by

different political or religious authorities. Unlike the solar calendar, the Islamic lunar calendar was never at risk of any long-term calendric splits.

The Sighting of the New Moon

The Islamic lunar calendar counts integer days, so months may be 29 or 30 days in length, in some regular or irregular sequence. The last day of the month of Sha'ban, for example, is often referred to as 'the day of doubt' in that it may or may not be the first of Ramadan, and the same is true for the last day of Ramadan, which may turn out to be the first day of Shawwal, if the lunar crescent has been sighted. The break from one month to the next can be different in different places when the sighting of the new moon occurs on different days, especially if the observers are far apart in longitude. In the premodern world, when communications were slow, this lack of uniformity did not matter very much.

The printed calendars available in today's book and calendar market list an alternating 30–29-day sequence among the 12 lunar months, starting with the first month, al-Muharram, at 30 days and ending with Dhu al-Hijja at 29 days. This civil calendar is the result of astronomical intercalation. To produce the most precise lunar calendar possible, the astronomers of the classical age (including al-Khwarizmi, as discussed below) designed a 30-year cycle of 12 lunar months of alternating 29 and 30 days. Eleven years of this cycle have 355 days, and the other 19 have 354 days; in this manner, the calendar stays adjusted to the lunar cycle and makes a complete circuit through the seasons in 33 years. While the calendar is thus fixed for civil purposes, for religious purposes the month starts with the first sighting of the new moon, and the day begins at sunset. For most Muslims, its true application now is mainly of ritual importance, especially when it comes to defining the beginning and end of Ramadan with its obligation to fast during daylight hours; the beginning of Dhu al-Hijja, which establishes the time frame for the Hajj and therefore the feast of sacrifice; and some other additional months that contain days of sacred rituals and festivals for some specific Muslim communities. Traditional practise has relied on eyewitness observation of the new moon by (usually) two appointed Muslim males of impeccable moral standing in the community (or one male and two females); after they had testified to sighting the first lunar crescent, the beginning of the new month was publicly announced by the authorities. But the issue is contentious, as different regions and authorities have asserted different opinions on how moon sightings should be determined (by observation or calculation or both) and whether moon sightings can be synchronized across larger regions.

Calculation or observation? Both? At some level, these age-old disagreements represent differences in time perception between the literalist and the interpretationalist scholars of Islam. As presented in Chapter 3, the Qur'an teaches God's sovereignty over time, His creation. Even though worldly time follows certain God-given rules, it can therefore not be autonomous, but represents a discontinuous galaxy of instants. In the words of Ulrike Freitag, refusal to determine religiously relevant time (such as the beginning of lunar months) by computation and insistence on eyewitness observation for validity are symbols of this aspect of time perception.

Support for calculation had been a minority position in the Sunni community of scholars from an early age. They based their support on Qur'anic verses such as 55:5 ('the sun and the moon serve computation [*husban*] of time'), 10:5 ('… He [God] determined [for the moon] stations, so that you may know the number of years and the reckoning [*hisab*] of time') or 2:189 ('they ask you about the new moons; say: they are fixed times [*mawaqit*] for the people, and for the Pilgrimage').

Eyewitness observation, however, remained the majority opinion. (It probably helped to reinforce this conservative status quo that only the 'extremist' Isma'ilis were in full support of calculations.) Despite this majority position, there always were some minority voices of dissent among the classical scholars of the Maliki, Hanafi and Shafi'i (though not the Hanbali) schools of law who argued against the total rejection of calculations to determine the beginning of Ramadan. Their blueprint was adopted by growing numbers of later jurists to whom exact knowledge of celestial bodies and computation of their movements was more accurate than sighting the new moon with the naked eye. As Jakob Scovgaard-Petersen has shown, the old question of calculation (rather than observation) of the new moon was taken up in Syria and Egypt with renewed vigour at the turn of the nineteenth to the twentieth century under the impact of a new technological device, the telegraph, which since 1865 had made it possible to receive reports from very far away that the new moon had been

observed. In 1902 the then mufti of Egypt, Muhammad Abduh (d. 1905), opined that the moon should always be observed with the eye, 'for the Islamic rulings are based upon what is simplest and easiest for people, wherever they may be'. Soon thereafter, however, several influential muftis argued that telegraphic reports on first-crescent visibility elsewhere must be accepted; they opined that the use of the telegraph 'will transform this observation from an individual obligation to a service rendered by society', meaning that it is 'in the general interest of humankind'. Over the past 100 years, a number of prestigious legal and theological scholars who likewise argued from the principle of 'general interest [of the community] [*maslaha*]' have opted in favour of adaptation of a scientifically-based lunar calendar. As listed in the *Fatwa on Astronomical Calculations* by the Fiqh Council of North America (see below), their group has included Sheikh Muhammad Mustafa al-Maraghi (d. 1945), Sheikh Ahmad Muhammad Shakir (d. 1958), his equally brilliant brother Sheikh Mahmud Muhammad Shakir (d. 1997), Sheikh Mustafa Ahmad Zarqa' (d. 1999), Sheikh Ali al-Tantawi (d. 1999), the contemporary Jordanian jurist Dr. Sharaf al-Quda, and many others.

Since midcentury, several attempts have been made to address the problem of a uniform lunar calendar and prayer timetable. The most ambitious project to date is a 'Three-Step Program to Create a Unified International Islamic Calendar' that began in 1975 with the formation of Malaysia's International Islamic Calendar Program, mainly organized by Dr. Mohammad Ilyas of the University of Science Malaysia. The programme requires the eventual conformity of all member states to the same 'expected visibility (IR) criteria' and acceptance of the concept of an international lunar date line for global uniformity. The first part of this project is said to be on its way to implementation. To date, Bangladesh, India, Pakistan, Oman and Morocco still require certification of actual sighting of the new crescent by a judge or review panel. In 1999 Saudi Arabia introduced the IR system into its national religious calendar; the legality of the system was further affirmed by the Organization of the Islamic Conference by way of a resolution adopted at its eighth session. Saudi Arabia now largely follows the convention that the start of the new month occurs on the first day after the new moon is calculated to set after the sun, meaning that the start of the month is based on a combination of physical sightings of the moon and astronomical calculations. The timing is regulated by the Institute of Astronomical and Geophysical Research at King Abdul Aziz City for Science and Research in Saudi Arabia. Qatar, Kuwait, United Arab Emirates, Bahrain, Yemen and Turkey follow the Saudi calendar. In Egypt, the new month begins when the new moon is calculated to set at least five minutes after sunset. Some communities (in Europe and the Caribbean) follow the first Muslim country to announce the new month. The Bohra, Ismaili and Qadiani communities have a precalculated calendar, while Nigeria's decision varies from year to year. But information on moon sightings can now be transmitted globally to branches of the Islamic network by telephone or fax (in some cases also e-mail), and national or communal decisions on first lunar visibility can be accessed globally through browsing the Islamic cyberspace. It is on the internet that today's believers can read the very latest data on how the lunar cycle translates into computer-calculated predictions of first lunar-crescent sightings the world over.

In the September–October 2006 issue of the journal *Islamic Horizons*, the Fiqh Council of North America published a two-page fatwa, written by council member Zulfiqar Ali, that supported calculation over observation in determining the beginning of the month of Ramadan. Even though acknowledging that this had been a minority legal position in the past, the council adopted the position

> because astronomical calculations in our times are not conjecture but are works of authentic scientists and astronomers who base their knowledge and calculations on scientifically observed facts. The margin or possibility of error in these calculations are close to zero […]. Now, calculations lend more certainty than the human eye […]. Therefore, the Fiqh Council of North America, meeting in Virginia on June 10, 2006, adopted this position to bring the Muslim community out of confusion and hardship.

According to Gary R. Bunt, the US-based Zaytuna Institute (founded by Sheikh Yusuf Hanson) offers nationwide information on moon sightings in the United States and Canada on its website Crescent Watch (www.crescentwatch.org); since both actual crescent sighting and confirmation by astronomical calculations are required in the United States and Canada, resources such as an Islamic calendar based on predicted moon sightings are integrated into this programme's format. Furthermore, links are provided to the Royal Greenwich Observatory and the Jordanian Astronomical Society (especially for information on the complex mathematical and theoretical bases for moon

sighting). Worldwide, the website Moonsighting (www.moonsighting.com) is an established and comprehensive resource on calendar and prayer calculations that includes discussion of the mathematics of these calculations. CyberSalat (www.ummh.net/software/cyber, which was created by Monzur Ahmed) contains a variety of Islamic and scientific resources for individuals to make their own calculations. Monzur Ahmed also offers an interactive Moon Calculator program (e-mail: monzur@bigfoot.com, monz@starlight.demon.co.uk as well as several home pages, including www.starlight.demon.co.uk/mooncalc).

Time and End-Time in Islamic Calendar Counting

Savviness in calendric counting, that is, to know just 'which year it was' in any part of the premodern Islamic world, may have remained of greater importance to the local historians, theologians and their political masters and tax collectors than to the population at large. But, as was true for Judaism and Christianity, the Islamic calendar was also open to numerological readings by apocalyptic-minded groups and actors, and therefore any approaching 'round numbers' in the calendar could mean that apocalyptic fears awakened an apprehensive awareness of chronology among the wider public or catalyzed some religiously-inspired individuals or groups to action.

There is an apocalyptic edge to some of the Qur'anic, especially the Meccan, revelations when they expound that the end is near: 'They see the [day] far off, but We [God] see it quite near' (70:6–7). 'The hour of judgement is near, and the moon is split' (54:1). 'Verily the hour is coming. My [God's] design is to keep it hidden, so that every soul be rewarded by the measure of its endeavour' (20:15). 'Closer and closer to people is their reckoning, while they in neglect turn away' (21:1). According to the (chronologically) earliest revelation regarding the hour, its appointed time is known only to God, and the Prophet is but a warner for those who fear it (79:42–6). This theme is reiterated in two late Meccan revelations, 'Verily the knowledge of the hour is with God alone. He sends down rain, and He knows what is in the wombs' (31:34) and 'The knowledge [of the hour] is with my Lord, none but He [can] reveal its time' (7:187), and also in a Medinan revelation: 'Men ask you about the hour. Say: knowledge of it is with God. What will make you understand? Perhaps the hour is near' (33:63).

The Qur'an identifies some of 'the signs of the hour' as the disintegration of established familial, societal and economic norms (80:34–7, 81:4, 70:10–14); 'a Beast of [or from] the earth' will arise (27:82); Gog and Magog will break through their ancient barrier wall and sweep down to scourge the earth (21:96–7); and Jesus is 'a sign of the hour' (43:61). But the eschatological themes of final struggle between good and evil and the kingdom of an end-time messianic figure on earth (the Mahdi) are developed in the Hadith far beyond their Qur'anic base. The Hadith also provides much more abundant information on the dissensions and trials of social disintegration and moral decay that signal the end. The Beast from the earth is often identified as Dajjal ('the Impostor') or al-Masikh or al-Masih al-Dajjal ('the False Messiah'). This Antichrist, who is either a beast, a monster or a human figure (whose appearance is often described in physical detail), seduces the Muslim community away from God's worship and establishes himself as their ruler for 40 years or perhaps 40 days. There is no consensus on whether this figure is identical with Satan/Iblis. To some, Jesus is the eschatological saviour whom the Hadith calls the Mahdi; to most others they are two distinct figures, based on their belief that the Mahdi is from the family of the Prophet. Jerusalem and Damascus are places mentioned for Jesus' Second Coming, Mecca for the Mahdi's reappearance. Jesus, the Mahdi or both together will kill the Antichrist.

Like the Christian Church, and for much the same reasons, Sunni establishment Islam took a dim view of apocalyptic movements that came with messianic claims and promises of this-worldly redemption. State-supporting Sunni ulama have therefore long found themselves in a precarious position between, on the one hand, public knowledge, often orally traded, of an abundance of eschatological traditions – large numbers of which are also found in even the most impeccable Hadith collections, the six *Sahih* books – and, on the other, their own role as scripturalist experts in government service. Over time the scholars have used and even expanded upon these texts, especially on the subject of the many 'signs that can be observed at present', to denounce religious aberrations and innovative and other objectionable (now especially West-imported) cultural, social and political practises in 'mirror of the times' fashion that aim to provide contemporaneous moral guidance by conveying a reversed (upside-down) vision of Godly society.

Some historians, prominent among them David Cook, have read the political events and

movements of early and later Islamic history as typically apocalyptic in nature, starting with the very first wars of expansion and including events of the years 100 Hijra (717 CE), 200 Hijra (815–816 CE), 300 Hijra (912–913 CE) and later. Most other historians opine that it was mainly with the Islamic Shi'a that apocalyptic millenarianism came into its own. After several failed attempts to wrest political power from the Umayyads and Abbasids (Husayn's martyrdom at Karbala in 680 and failed uprisings in 689, 758 and 864 CE), however, the Shi'ite 'dynasty' of Husayn's successors in the imamate increasingly withdrew from politics to concentrate on developing Shi'i doctrine and law. Simultaneously, the concept of occultation gained prominence in their theology. With the declaration of the Twelfth Imam's Major Occultation in 939 CE, the Imamites (Twelver Shi'ites) reinforced their position of political quietism; the Hidden Imam would return at a future point in time that was 'known only to him and God'. With this doctrine, the Twelver Shi'a also distanced themselves from the activist and revolutionary agenda of the (Sevener Shi'ite) Isma'iliyya that held attractions for many of the Shi'i faithful at that time. In this fashion, the Twelver establishment opted to deal with their eschatological traditions much as the Sunni theologians did: cautiously. Their millenarian Hadith contained detail on the political and social turmoil of their own time in the form of prophesies, followed by prophesies on the final outcome, but the emphasis was on the duty to wait patiently.

This (quietist) 'corporatist' position of Muslim religious establishments, Sunni as well as Shi'a, has neither forestalled popular apocalyptic apprehensions or expectations nor prevented reformers and revolutionary activists, both Sunni and Shi'a, from appropriating an apocalyptic framework for their activities. A brief glance at sources contemporaneous with the turn of the Hijra calendar from its first to its second millennium (1000 Hijra = 1592 CE) indicates that the date did indeed awaken widespread apocalyptic fears and expectations in the Islamic world. A contemporary, the Ottoman bureaucrat and intellectual Mustafa Ali (1541–1600), described the end-of-the-world mood that was gripping Istanbul (Constantinople, Qustantiyya) on the eve of AH 1000, when the date was preceded and intensified by three years of evil omens: a Janissary uprising, provincial revolts, two great fires and a plague. Even though Mustafa Ali affirmed that he personally did not believe that the end was approaching, he went along (perhaps largely for reasons of failed professional expectations) with the millennial mood of Istanbul. When the calendar had turned and the world was still intact, his own personal mood also changed to one of contemplation and nostalgia.

The letters of another eyewitness to the millennium, the Moghul Emperor Akbar (1542–1605), make no mention of the event. India at the time adhered to the old, solar, Persian calendar instituted by Yazdigird III in 632 CE, in its eleventh-century Seljuk refiguration, an astronomical masterpiece calculated by the astronomer and poet Omar Khayyam (d. 1123). Named in honour of the Seljuk sultan Jalal al-Din Malikshah, this Jalali calendar had first been introduced on Nawruz ('new year's day', the vernal equinox, 15 March 1079 of the Julian calendar, which would later correspond to 21 March [on this calendar; see also Chapter 6] 1079 of the Gregorian calendar, and 9 Ramadan 471 of the Hijra calendar). Emperor Akbar made it the official calendar of Moghul India in 1584 CE (AH 992), but he did so retroactively, decreeing that the calendar's epoch was 28 years earlier, the vernal equinox of the year of his coronation (1556 CE, AH 964). In AH 999/1000, Akbar therefore had no numerically alarming threshold to cross. Nevertheless, he was aware of a Muslim millenarian tradition that viewed the turn of the first Hijra millennium as potential fulfilment of the earth's 7,000-year life span, as well as of the fact that in some Indian Muslim circles his own person was identified with the messianic figure, the Mahdi, expected to appear at the end of time. For his own reasons, Akbar appears to have supported both assumptions.

Islamic history provides abundant examples of Mahdi figures who rose with millenarian claims and intentions, some of whom found establishment support. On the cusp of year 1300 in the Hijra calendar, the Sudanese Muhammad Ahmad al-Dunqulawi publicly announced himself to be the Expected Mahdi; the date, June 1881 CE, corresponded to AH 1299. This Mahdi saw himself as the successor to the Prophet and also as the divinely elected Mahdi, called to end the innovations and tyranny of the Turco-Egyptian regime over the Sudan. The Sudan's Sufi tradition imparted a strong eschatological dimension to his ideas. The February 1979 Iranian revolution (AH 1399) likewise used apocalyptic material to communicate the urgency of its (and Khomeini's) reformist message.

A separate example of how 'round numbers' qua 'sacred numbers' can function as catalysts of apocalyptic activities is the 20 November 1979 takeover of the Holy Mosque in Mecca. In this case, institutional support was lacking, but the calendar date was significant: in the dawn hour of New Year's Day, 1 Muharram AH 1400, a group of Arab Muslim revolutionaries occupied the Meccan sanctuary and proclaimed that the Mahdi had come. This was a momentous date, because – according

to a popular apocalyptic tradition – 5,000 years separated Adam from Jesus, and 600 years separated Jesus from Muhammad, so that the year 1400 of the Muslim calendar signified the year 7000 in world history, which God had decreed as Creation's end. The core group of the rebels was formed of young puritanical Saudis, several of them former law and theology students at Mecca and Medina. Their Mahdi was Muhammad ibn Abdallah al-Qahtani, whose 'signs' fulfilled the eschatological Hadith in that he was of the Prophet's tribe, had proclaimed himself a descendant of the Prophet, his and his father's names were the same as the Prophet's and the Prophet's father's and he had arrived in Mecca from the North. The real leader of the group, Juhayman ibn Muhammad al-Utaybi, had tribal as well as ideological links to the Saudi Ikhwan of the 1920s (first organized and later largely eliminated by Abd al-Aziz ibn Saud, founder of the present kingdom), and he was known for previous attacks on the alliance between the ruling dynasty and the clergy, accusations of their shared corruption, and castigations of modernization and all modern devices in the kingdom. The ulama, in alliance with the royal family, issued a fatwa that permitted the use of military force to remove the rebels from the Holy Mosque and kill the pretender for sowing dissension among the faithful. As it turned out, al-Qahtani was killed during the protracted struggles in the sanctuary, while al-Utaybi and 62 of its followers and disciples were executed by the Saudi authorities on 8 January 1980.

At present, apocalypticism has gone more global than ever before. The internet has given apocalyptic prophecy a new, pervasive and persuasive medium, but apocalyptic transcultural contagion is now also instantaneous. The year 2000 CE became one of its symbols. It brought a shared rise in apocalyptic temperature among extremist Jewish, Christian and Muslim groups whose fervour was mutually stoked by the internet, while their visions remained mutually exclusive. Each religion perceives the millennium in terms of its own global vindication. The year 2000 CE thus also marked a high point in Arabic apocalyptic literature on Islam's final battle, victory and redemption, even though the date on the Hijra calendar was a bland AH 1420.

CHAPTER 3

TIME, THE QUR'AN AND SCIENCE

Time in the Qur'an

The Qur'an's vision of time is God centred. Time is not an abstract force. The revelation (45:24) rejects the pre-Islamic concept of *dahr*, 'fatalism of impersonal time' or 'blind destiny', as a pagan fallacy. There can be no impersonal time, because God, ruler of the universe who is beyond time, is Lord over time at both the beginning and end of Creation, just as He is Lord over time during all of mankind's intervening, individual and collective instances of historical time. The Qur'an thus defines time from the perspective of a transcendent and omnipotent God who obliterates the spell of fate and subdues the all-pervading power of time, since both are His creations. While time is a function of God's omnipotence, so is its measurement, a divine gift that God created for the benefit of humankind. The Qur'an deals with aspects of time in richly designed concrete and practical examples that establish God's authorship of all celestial movements and their usefulness to the human race as devices to measure time. The computation of days, months and years is rooted in God's will.

Night and Day

Night and day are among the signs of divine power and divine providence (17:12: 'We have made the night and the day as two signs, the sign of the night We extinguished [or: obscured] while the sign of the day We made clear so you may seek bounty from your Lord by working] and may know the number and accounting of the years'; 73:20: 'God appoints night and day in due measure'; 2:164: 'In the creation of heaven and earth, in the succession of day and night, in the ships that sail the ocean for people's benefit, in the rain that God sends down from the sky to revive the earth after it has died, in all the beasts that He scatters throughout the earth, in the change of the winds, in the clouds made subservient between sky and earth, therein are signs for people who have minds'; 3:190: 'In the creation of heaven and earth, in the alternation of night and day, there are signs for people who have minds'; 10:6: 'In the alternation of night and day, and all that God has created in the heavens and on earth, there are signs for people who fear God'; 23:80: 'It is He who gives life and death, and to Him is due the alternation of night and day'; 45:5: 'The alternation of night and day, and the sustenance that God sends down from the sky to revive the earth after its death, and the changing of the winds, are signs for people who have minds').

God brings forth the day from the night (35:13: 'He merges night into day, and He merges day into night, and He has subjected the sun and the moon so each runs its course for an appointed time'; 7:54: 'Your Lord is God who created the heavens and the earth in six days, then assumed the Throne. He covers up the day with the night which comes chasing it fast, and the sun, moon, and stars are subjugated to His command. It is His [or: to Him] to create and command'; 36:40: 'The sun may not overtake the moon, nor the night outstrip the day. Each swims in a celestial orbit'; 31:29: 'Do you not see that God merges night into day and merges day into night, and sun and moon are subjugated to His command, each running its course for an appointed time'; 39:5: 'He truly created the heavens and the earth, He winds [or: rolls] the night [like a turban] to overlap the day, and the day to overlap the night, He has placed the sun and moon into service, each follows a course for an appointed time'; 57:6: 'He merges night into day and merges day into night, and He knows [the secrets in] the hearts').

God created night and day for a purpose (71:16: 'Do you not see how God has created seven heavens in layers, and the moon as a light and the sun as a lamp in their midst'; 25:47: 'It is He who makes the night as a garment for you and sleep as a repose, and the day for waking up'; 27:86: 'Do

they not see that We have made the night for them to rest in it, and the day for them to see clearly'; 28:73: 'It is out of His mercy that he has made for you night and day, that you may find rest in it [the night] and that you strive for His grace [in the day]. Perhaps you would be grateful'; 40:61: 'God has made the night for you to find rest in it, and the day to see clearly').

Time moves in the measurable rhythm of sun and moon, where the sun provides the means to tell time and the moon and its phases provide the means to calculate the months and years (6:96, 55:5: God created sun and moon as a pair for 'reckoning' time [*husban*]; 25:45: 'Stretching out the shadow [in the morning] – if He willed, He could make it stationary,' and then appointing 'the sun to be an indication [or: guide] for it [the shadow]'; 36:37: 'And a sign for them is the night: We strip the day away from it, and suddenly they are in darkness'; 36:38: 'And the sun runs its course to its fixed resting place [*mustaqarr*]'; [to the ancients this was a place on the sun's orbit to prostrate itself and rest briefly under God's throne before rising again; contemporary translations usually render this phrase as 'the sun running its course for a period determined for it']; 36:39: 'And for the moon we have decreed stations [*manazil*] until it is again like an old [withered] palm-bough'; 36:40: 'It is not permitted to the sun to catch up with the moon, nor can the night overtake the day. All are swimming in a celestial orbit').

We will deal with the intervals of day and night, such as dawn and dusk, noon, sunset and the like in Chapter 7, 'Time Sticks'. in what follows.

The Week

The week is a purely conventional unit of time measurement that is independent of celestial phenomena. The week is not cited in the Qur'an. It was known in pre-Islamic Arabia and used by the early Muslim community. The Qur'an once mentions Friday (*yawm al-jumu'a*) as the day of special congregational prayer obligation (62:9) and also refers to the Jewish Sabbath.

The Month and Year

Time is reckoned on the basis of the observation of lunar phases called *manazil al-qamar* ('stations of the moon') (36:39, 10:5) and the 'mansions' (*buruj*, 'towers') of the signs of the zodiac (15:16, 25:61, 85:1). In Qur'anic exegesis, the 'stations of the moon' have been understood by some as the stages, or phases, of the moon in the Islamic lunar calendar. For most other interpreters as well as the astronomers and astrologers, the notion of 'lunar stations' constituted a lunar zodiac (presumably first developed in India) that signified the 28 stars or constellations in which the moon 'stations itself' each night of its sidereal revolution around the earth. A sidereal revolution (the moon's revolution in its orbit from a star back to the same star) is not equivalent to a lunation (the time between identical phases of the moon) in that its duration is only about 27 1/3 days, a number not applicable to the lunar calendar month of 29 1/2 days. The selection of 28 stars or constellations that the moon regularly conjoins each night of its sidereal revolution, however, in and of itself provides a rough guide for charting the nightly course of the moon and may have been in use as such in pre-Islamic Arabia.

In pre-Islamic Arabian practise, the night sky was read to determine the hour of the night and the season of the year. The agricultural seasons, conjoined with meteorological prognostications, were linked with the annual rising of certain stars or with the rising or setting of the 'lunar stations'. According to Daniel Varisco and others, the Qur'anic 'stations of the moon' may therefore be remnants of an indigenous pre-Islamic Arabian star calendar (and thus quite unrelated to the zodiac), which had also regulated some pagan practises entailing the magical use of stars for invoking rain. Thus, it may have pertained to the pre-Islamic system of *anwa'* ('reckoning time on the basis of the rising and setting of stars'), not mentioned in the Qur'an but used by the pre-Islamic Arabs to estimate the passage of time and predict (and perhaps magically influence) the state of the weather. Islamic science obliterated this pre-Islamic calendar of 'stations' (with its pagan connotations) from memory by defining 'the stations' as part of a lunar zodiac where each station represented an equal (prorated) amount of arc along the moon's entire monthly course of 29 or 30 days. This provided them with a practical system of lunar-calendar-pegged coordinates for use in navigation and timekeeping.

In the Qur'an, the key to accounting months and years is the moon. In Sura 10:5, the Qur'an reminds us that 'it is He who made the sun a brightness, and the moon a light, and measured out stages [or: stations, *manazil*] for it, so you would know the number of years and the accounting [of

time]'. Each lunar month begins with the sighting of the new crescent in the evening sky (2:189: 'They ask you about the new moons. Say: they are appointed times [*mawaqit*] for the people, and for the Pilgrimage …'). God decreed that the year be divided into 12 months (9:36: 'The number of months in the sight of God is twelve, in God's Book the day He created heavens and earth. Of them four are sacred. This is the right religion. So do not wrong yourselves in them [the four sacred months], and fight the pagans all together as they all together fight you, and know that God is with those who fear Him'). The names of the pre-Islamic sacred months, Dhu al-Qa'da, Dhu al-Hijja, al-Muharram and Rajab, are not mentioned in the Qur'an, but there are allusions to them in 9:2 ('travel around freely in the land for four months') and 9:5 ('when the sacred months are past, then kill the pagans wherever you find them'). This divinely decreed 12-month, moon-based calendar eliminated the pre-Islamic practise of intercalation of a thirteenth month that the pre-Islamic lunisolar year had required (9:37: 'Intercalation is an excess in unbelief [or: is an addition to disbelief; or: is but an increase in unbelief]. Those who are [already?] unbelievers are thereby [even more] led into error. They declare it [the month of al-Muharram?] lawful [*halal*] in one year and declare it forbidden [*haram*] in another, in order to adjust the number of months forbidden by God and make such forbidden ones lawful [for fighting]. The evil that they do seems pleasing to them. God does not guide the unbelieving folk'). In the preceding section on the Islamic calendar, we dealt with the changeover from the lunisolar Arabian calendar, with its practise of periodic intercalation, to the strictly lunar Islamic calendar that the Prophet embraced in 632 CE.

Of the 12 lunar months, only the month of Ramadan is mentioned by name in the Qur'an. It is the month of fasting, now the ninth month in the Islamic lunar calendar (2:183: 'Oh believers, it is prescribed for you as it was prescribed for those before you, perchance you will fear God'; 2:184: '[Fasting] a fixed number of days. If one of you is sick or on a journey, then a number of other days. For those who can do it, a ransom, the feeding of one pauper. He who gives more of his own free will, it is better for him. And it is better for you that you fast …'; 2:185: 'The month of Ramadan in which the Qur'an was sent down as a guidance for mankind and clear proofs of guidance and evidence. Whoever of you is present [at home], let him fast in it. Who is sick or on a journey, then a number of other days. God wishes to make it easy for you, not difficult. So that you may complete the number and praise God that He has rightly guided you …'). Qur'an 97:3 specifies that God revealed His message to the Prophet 'in the Night of Power' (*laylat al-qadr*) that is 'better than a thousand months', while according to Qur'an 8:41 the revelation was sent down on 'the Day of Testing' (*yawm al-furqan*); *furqan* is also the name of the battle of Badr (624 CE). In scholarly exegesis as well as popular piety, the Night of Power is variably identified as the seventeenth or nineteenth, twenty-fourth or twenty-seventh night of the month of Ramadan (see 'Al-Biruni on the Festivals of the Muslims' in Chapter 6).

The only other month that the Qur'an identifies, not by name but by function, is 'the holy month' (*al-shahr al-haram*), which is generally assumed to refer to the month of Dhu al-Hijja, month of the pilgrimage to Mecca and now the twelfth month in the Islamic lunar calendar. The Qur'an in 2:194 makes retaliation in 'the holy month' lawful; 2:195 calls upon the believers to spend (of their wealth) in the way (or: for the sake) of God; and 2:196–203 proclaim the rules and regulations concerning the Hajj (Greater Pilgrimage) and 'Umra (Lesser Pilgrimage). In addition, Sura 5:2 and 5:97–100 specify that wild terrestrial (not aquatic) game is forbidden (to kill or to eat) during 'the holy month' for pilgrims who are in the state of ritual consecration (*ihram*). The first ten days of Dhu al-Hijja are called 'sacred days' (see 'Al-Biruni on the Festivals of the Muslims' in Chapter 6).

Time as Metaphor

A larger theme in the Qur'an's dissertation on time emerges from its metaphorical use of human calendric terms (year, month, day, hour) to proclaim the divine secrets of God's Creation, mankind's fate from womb to death to Judgement Day and the terms of Creation's termination and elimination. Categories of time measurement are employed to proclaim creational and eschatological mysteries by way of metaphor. It is perhaps noteworthy that 'the month' does not pack much of a punch as a metaphor but largely serves as a gauge of temporal weight and duration in the Qur'anic legal discourse (2:226: 'Those who take an oath of abstention from their women must wait for four months'; 2:234: 'Widows must wait for four months and ten days' before they can remarry after their husband's death [but, 65:4, only three months if they are menopausal]; 46:15: 'The bearing and weaning of a child takes thirty months', which relates to 2:233: 'mothers should nurse their children for two whole years').

In contrast to the month, ‘the year’, ‘the day’ and especially ‘the hour’ are prominently employed in mapping out the Qur'an’s creational, miracle-working and, eventually, eschatological scenarios. Their largely metaphorical function in these dramas is therefore at least threefold: to explain the creational mystery, to present an alternate, symbolic accounting in situations where ordinary, historical, time has been suspended, and to instruct a feeble and doubting humanity about the magnitude of the events at the world's end. God is above ordinary time (22:47 and 32:5: ‘A day in the sight of your Lord is a thousand years’; 70:4: ‘The angels and the Spirit ascend to Him in a day whose measure is 50,000 years’). The fact that He created the heavens and the earth in six days (7:54, 10:3, 32:4, 25:59, 11:7, 50:38, 57:4) is a prime example of God's lordship above and outside of time, which itself is His creation. Furthermore, God can of course suspend ordinary time. In the Sura ‘The Cave’ (*surat al-kahf*, the eighteenth Sura of the Qur'an), God took a group of believing youths together with their dog away from human time to save them from persecution (18:11: ‘God sealed the ears of the seven sleepers for a number of years’; 18:19: ‘He awakened them so they would question each other [about the length of their sleep] and they guessed that it had been a day or part of a day’; 18:25: ‘They remained in their cave three hundred years and nine more’; 18:26: ‘God knows best how long they stayed: He owns what is hidden of the heavens and earth’).

Metaphorically, ‘day’ is also the ‘day of doom’ that signals a stage in the eschaton, such as ‘the last day’ (*al-yawm al-akhir*, cited 38 times), the ‘day of resurrection’ (*yawm al-qiyama*, 70 times), the ‘day of judgement’ (*yawm al-din*, 13 times), the ‘day of decision’ (*yawm al-fasl*, six times) and the ‘day of reckoning’ (*yawm al-hisab*, three times). The term *hour* is even more frequently employed to denote the final stage in the world's existence and history. We have already presented some of the Qur'an’s citations on ‘the hour’ in its eschatological meaning in the section on the Islamic calendar. Only God knows ‘the hour’ (7:187; 33:63; 41:47; 43:61, 85) that is near (33:63, 42:17, 54:1, 16:77). ‘The hour’ is coming (15:85; 18:21; 20:15; 22:7; 30:12, 14, 55; 40:59; 45:27, 32), it comes suddenly (6:31, 12:107, 22:55, 43:66, 47:18) with its signs and tokens (*ashrat*, 47:18, 22:1, 54:46) and brings God's chastisement (6:40, 19:75, 40:46). God-fearing people tremble because of ‘the hour’ (21:49), while the unbelievers are in doubt or denial about it (18:36, 25:11, 34:3, 41:50, 42:18, 45:3).

In a fairly typical, mass-market traditionalist Islamic primer on the notion of time entitled *Time between this World and the Next* (*Al-zaman bayna al-dunya wal-akhira*, published in Cairo in 1997), the author, Abd al-Ghani Abd al-Rahman Muhammad, places the study's primary emphasis on the *akhira* (‘hereafter’) dimension, meaning that its primary focus is on the transcendental import of the Qur'anic message. While the sections on years, months, days and hours in this primer do indeed deal with the astronomical underpinnings of human calendars and their various readings by human interpreters and practitioners, the main focus of the work lies with the metaphorical nature of the Qur'anic message on time, most especially its eschatological role as portent of the hour that will mark the world's end. The primer has an additional and practical feature, however, which is to instruct its readers on ‘how to measure abstract/universal/non-local-specific time’ in the absence of an appropriate time-measuring machine for this purpose, such as a mechanical clock, a modern watch, an hourglass or even a *klypsadra* (ancient water clock). (The question of ‘local’ or ‘seasonal’ versus ‘universal’ time is discussed in several of the following sections). One would think that the use of ‘universal time’ has steadily encroached upon the use of ‘local time’ the world over, but where the time schemes of the premodern world with their seasonally variable minutes and hours still prevail. Abd al-Ghani Abd al-Rahman Muhammad's primer offers a popular device to measure ‘universal’ time by the oral rendition of sacred texts. While health-conscious Americans are instructed in the US media to brush their teeth morning and night for two minutes each time, or as long as it takes to slowly say, sing or think the entire jingle of ‘Happy Birthday’ ten times over, Abd al-Rahman Muhammad says that, for example, one minute in abstract or universal time equals pronouncing the five words of the Basmala and the four words of the first phrase of Sura 112, a total of 30 times, and he provides many other such formulas as well.

The Qur'an and Science in the Classical Age

As the historian and philosopher of science Thomas Kuhn termed it in the 1960s, a paradigm is a frame of perception and also a guide to action. In premodern Islam, the Qur'anic paradigm and the paradigm of science coexisted, largely without mutual interference. Scientific activity was integrative with, rather than marginal to, mainstream intellectual life in Muslim societies. In the words of Ahmad Dallal, the integration of religion and science was in part due to the ‘naturalization’ of some of the

exact sciences, including astronomy, that were provided with Islamic justifications. Some religious scholars were themselves competent scientists. Perhaps more important, however, was the systematic 'mathematization of astronomy' that opted for theoretical and epistemological models over the philosophical. According to Dallal, this reform tradition was specific to the Eastern part of the Islamic world; the Islamic West went the other way to uphold the (meta)physical theories of Aristotle, Ptolemy and their disciples (see Chapter 4). Having developed 'the mathematical principles to replace the older physical, or rather metaphysical principles of astronomy', the Eastern tradition separated science from philosophy, and eventually relegated philosophy to one among many other sciences and thus reduced the areas in which scientific knowledge and religious knowledge overlapped. Muslim scientists, such as al-Biruni (d. *c*. 1050 CE), argued that it was the very separation of religious and scientific knowledge that preserved the truthfulness and validity of both. The great Qur'anic exegetes of the classical age profoundly shared this opinion. As scholars of scripture, whether traditionalist or rationalist or mystic or a combination thereof, their approach to the holy text was theological. It focused on the core Qur'anic doctrines of God's unity, God's omnipotence, His absolute freedom and lordship over creation, and also the wisdom and kindness by which He had designed the universe for the benefit of humankind. Human knowledge is unable to grasp these mysteries, except to acknowledge the utter contingency of all natural phenomena on the Creator; since natural phenomena can have multiple scientific explanations of uncertain validity, the only remaining certainty is that all creation is from God, who makes all the choices. This worldview does not translate into binding scientific facts.

The relationship between the Qur'an and science was, nevertheless, an important theme in Qur'anic exegesis (*tafsir*, pl. *tafasir*), the most prominent genre of Muslim scripturalist learning where some of the best minds in the premodern Islamic world delved into the doctrines of the holy text while also engaging in the larger cultural debates of their own place and time. Classical Qur'an commentaries often introduced discussions on scientific subjects, and on occasion even employed science-derived arguments, to illustrate specific aspects of their Qur'an-based paradigm. The heart of that paradigm was the marvel of Creation, and how this mystery is of benefit to mankind in both this world and the next. Finite humanity is unable to grasp the infinite knowledge, power and wisdom of God. Therefore, the ultimate purpose of reflection is not to seek or find proof of scientific facts in the Qur'an, but to gain a deep awareness of the limitations of human knowledge, indeed, of man's inability to comprehend Creation. The more a human being immerses him- or herself in the contemplation of 'God's signs' in Creation, the more clearly will he or she perceive the limitations of his or her own intellect and the more deeply will he or she then believe in the magnitude of God's power; this is the religious benefit of contemplation that for the believer will garner its best fruits in the world to come. By self-definition, this Qur'an-based paradigm has no room for a notion of self-sustaining 'natural order', and indeed the classical exegetes did reject such explanations of Qur'anic verses that were grounded in that notion.

The rationalist (more than the traditionalist) theologians frequently engaged in quasi-scientific discussions that drew on science. Even if they were knowledgeable about the scientific debates of their day, however, these classical exegetes did not privilege science as an authoritative 'proof' in scripturalist exegesis. Both theologians and scientists conceptualized religious and scientific knowledge as mutually independent forms of intellectual enterprise, neither employing the Qur'an to assert the scripture's authority over scientific knowledge nor reversing the process by arguing that the miracle of the Qur'an lies in its prediction of scientific discoveries. Here we might press a medieval theologian and a medieval scientist into service by quoting some of their writings on the issue of revelation and science.

The Theologian

When he wrote his magisterial commentary on the Qur'an, the most prominent medieval Muslim theologian of the rationalist school, Fakhr al-Din al-Razi (d. 1210), emphasized that science was but one of the useful ancillary arts in the interpretation of scripture. For the knowledgeable it enhanced their faithful understanding and awe of the miracle of God's Creation and strengthened their gratitude for the intricate workings of a cosmic order (of 'the heavens, earth, and what is in between'). In interpreting Sura 7:54, for example, al-Razi emphasizes that the main message of this revelation is to certify God's limitless creative power and wise plan for the universe. The verse reads:

> Your Lord is God who created the heavens and earth in six days, then assumed the Throne.

> He covers up the day with night, which comes chasing it fast; and the sun, moon, and stars are subjugated by His command. It is His [or: to Him] to create and command. Blessed be God, Lord of the worlds.

Before embarking on the interpretation of this verse, al-Razi lists four overriding Qur'anic themes: the oneness of God, prophethood, resurrection and God's omnipotence and power (of predestination). The verse, he maintains, relates to all these themes, most directly to the first and fourth, God's unity and God's power.

On the creation of the heavens and the earth and the origin of time, al-Razi states the theory both that the universe is eternal and that God created it *ex nihilo*, out of nothing. Both issues were debated at his time. The former (in his Islamic answer to the pagan Greek philosopher Aristotle) was the position of the philosopher Ibn Sina/Avicenna (d. 1037) for whom the heavens exist eternally but are themselves eternally dependent on God. The latter was the position of the mainstream religious establishment, most prominently given voice by the theologian al-Ghazali (d. 1111) who regards both time and the world, including the heavenly bodies, as being created from naught. Al-Razi solves the problem by saying that if the heavenly bodies were preexistent before Creation, they were immobile, and thereafter were made to move by a creational act of God. If, on the other hand, they were nonexistent, they were created *ex nihilo*. In either case, God created the heavens and the earth by His decree.

To al-Razi, the specific size and location of each celestial body as well as the seven planets' distinct colours and patterns of motion are clear indications that all were created in this – and no other – form by a willing maker endowed with power and choice. The same applies to the time of their creation, which is likewise an act of God and not due to any of the objects' inherent nature. The occurrence of that origination in six days, or any other number of days, has no pertinence to the argument, except that the time-frame itself is indicative of divine choice. Al-Razi deals with the 'six days of creation' issue by saying that God revealed at the beginning of the Torah that He created the heavens and earth in six days, and since the Arabs used to mingle with the Jews, it appears that they heard the story from them. So it is as if God is saying (to the Arabs): do not engage in idol worship, for God is He of whom you have heard knowledgeable people say that He created the heavens and the earth – despite their size and utmost majesty – in six days (only). Furthermore, even though God has the power to bring into existence all of creation all at once, God created the world bit by bit, not because of fatigue or negligence, but to teach His servants gentleness and patience; it is in the same vein that God defers the punishment of polytheists and those who give His prophets the lie, granting respite not because of fatigue or neglect, but because the granting of respite is – or can be – beneficial.

According to al-Razi, the words '[He] assumed the Throne' cannot be understood in spatial or physical terms, because that would render God finite and would render the Throne a spatial object. The earth is a globe, meaning that it is round. Therefore, we cannot think of God as being 'above'. If God were in a finite space, He would be above some people, below others, right of some and left of others, in front of some and behind others, none of which is conceivable with regard to God. Therefore, the meaning of the phrase '[He] assumed the Throne' is obscure (*mubham*); we entrust its meaning to God, except to say that the Throne as the seat of power stands for divine sovereignty and majesty.

'He covers up the day with night, which comes chasing it fast.' In this part of the verse, says al-Razi, God informs of the tremendous benefits that arise from the succession of night and day, by which life is accomplished and well-being perfected. God describes the movement (of night and day) as rapid and forceful, which is true because the succession of night and day occurs by the movement of the 'great [outer] orb' (the sphere of the fixed stars), which is the swiftest and most forceful of all movements; indeed, scientists have said that by the time a speed racer has lifted one foot and placed it back on the ground, the great orb has moved 3,000 miles. 'And the sun, moon, and stars are subjugated by His command.' The sun, says al-Razi, has two cyclical motions: one that is completed in a year, the other in a day. Night and day, however, are due not to the movement of the sun but to the motion of the great outer orb, which is also God's Throne. Moreover, God assigned to each planet and each star an angel who moves it when it rises and when it sets. And He endowed the great outer orb, the Throne, in the eighth heaven with the power to influence all the other orbs, of which there are seven, one for each planet, so that it moves them by compulsion from East to West in the direction opposite to their own, slow, West-to-East motion. In the great outer orb of fixed stars, each star likewise has its own pace of West-to-East rotation; stars closer to the equator move faster than those

closer to the pole. The closest star to the pole, the North Star (‘of which the uneducated say that it is, itself, the pole’), moves in an extremely small orbit that it completes ‘once every 36,000 years’. According to al-Razi, there are no movements on earth to equal either the slowest or the fastest movements that exist in the celestial sphere. But to al-Razi, the primary meaning of ‘subjugation’ is that orbs and planets are organized by God in a particular order, created for no other reason than to produce the most optimal benefit for humankind.

It is worth noting that the theologian al-Razi's interpretation of Sura 7:54 takes cognisance of some quite specific astronomical data that indicate his familiarity with cosmological theories and models debated by the Muslim scientists of his time. Clearly, al-Razi had learned the notion of an eighth sphere, or orb, from Ptolemy who, in turn, had it from Aristotle in whose cosmology the eighth orb is needed to account for the motion of the stars. Furthermore, according to Aristotle's *Metaphysics*, the motion of every orb is produced by its own unmoved mover. In al-Razi's Qur'an commentary, this Aristotelian doctrine is harmonized with an Islamic worldview: each of the multiple orbs in each planet's system is turned by an angel of God. (The very same ‘compromise’ on this item between Aristotelian physics and the Christian worldview can later be found in several Christian commentaries on Aristotle's *Metaphysics.*) On the other hand, al-Razi's figure of 36,000 years for a star's complete rotation cycle is derived from Ptolemy. The rise of Islamic science is discussed in Chapter 4, together with an introduction to the older cosmological theories and models whose imprint can here be traced in the example of al-Razi's exegesis of Qur'an 7:54.

Al-Razi concludes his interpretation by saying that some ignorant people have criticized him for his copious use of astronomical data as being ‘in conflict with what is customary’. His reply to these critics is that if they truly reflected on God's Book, they would know better. God filled His revelation with information about His knowledge, power, wisdom and all the details pertaining to the heavens and earth, the sequencing of night and day, light and darkness, sun, moon, stars and the like; if it were not permissible to discuss and contemplate this information, He would not have filled His revelation with it. When God said, ‘Have they not looked to the sky above them, how We have constructed it and embellished it, and that it contains no flaws’ (Sura 50:6), He is urging us to contemplate how He built it. The science of astronomy has no meaning other than to contemplate how He constructed and created each part of it. The creation of the heavens and the earth is more wondrous and perfect than the creation of the human being (Sura 40:37). Indeed, God praised those who think about creation, when they say ‘our Lord, you have not created this in vain’ (Sura 3:191). Therefore, the believer who is more (scientifically) informed about the intricacies and subtleties of God's Book has the more complete belief in its exaltedness and majesty. According to al-Razi, then, science in general and astronomy in particular can perhaps enrich theology by providing detail that deepens human understanding of the revelation. But his *tafsir* quasi-scientific discourse neither aims to uphold a specific scientific theory nor aims to contribute to the accepted body of scientific knowledge. In the final analysis, its data is always secondary because the Truth has already been established in the revelation that is eternal in both nature and validity.

The Scientist

Younger than al-Razi by about a century and a half but equally high-powered, the astronomer, mathematician, physicist, historian and ethnographer al-Biruni (d. *c.* 1050) – the subject of much that is to follow – also saw his own work in the natural, abstract and human sciences as sanctioned by the Qur'anic revelation. He often wrote about the value of science in the human quest for religious certainty. Indeed, he maintained that science, rather than mere scripturalism, was the more enlightened way to understand the rules of the universe and therefore its Maker. Al-Biruni was steeped in the scientific culture of his age whose roots lay deep in the soil of extra-Islamic civilizations; he knew Archimedes, Euclid, Apollonius and Ptolemy by heart and spoke of the calculation of conic sections as ‘spiritual geometry’ (see Chapter 4). In a brief paragraph found in his work *Determination of the Coordinates of Positions for the Correction of Distances between Cities* (*Kitab tahdid nihayat al-amakin li-tashih masafat al-masakin*), for example, al-Biruni ascertains the following:

> If a worshipper is a truth seeker, then he is eventually led to an investigation of the old and new conditions of the world, and if he ignores that investigation, he can not pursue truth without reading intelligently about the rules of order in the universe and its parts, and without investigating the validity of those rules. The investigation will acquaint him with the Maker and His deserving qualities; and the knowledge of these qualities is the *sine qua non*

> for the recognition of a revealed prophecy, because their identification is essential to discrimination between a proper and a pseudo prophet. The pretenders to revelations are many, and since they do not agree among themselves, it is certain that some of them are false pretenders who would lead people astray. This point of view is that which God Almighty would accept from His servants. He says, and what He says is luminous truth: 'Those who remember God … and contemplate the [wonders of the] creation in the heavens and the earth' [react by saying] 'Our Lord, not for naught hast Thou created [all] this' [Qur'an, Sura 3:191] … Until a man is not truly disciplined by the instructions he cannot truly realize the essence of wisdom in all forms of science and knowledge. There are two alternatives: either he would take it as a story and a tradition, or he would scientifically investigate and realize the truth it contains. But surely there is a great difference between an investigator of truth and a follower of tradition. God says: 'Are those equal, those who know and those who do not know? It is those who are endowed with understanding that receive admonition' [Qur'an, Sura 39:]). A traditional follower of these principles is as ignorant as a traditionalist who follows what is derivable from them. (Translated by Jamil Ali, American University of Beirut, 1967)

What does al-Biruni mean when he says that true knowledge of the validity of the rules governing the universe is the *sine qua non*, the one required condition, for recognizing a revealed prophecy's authenticity? In other words, is it that a scripture's truth to the laws of the cosmos proves that the revelation is equally true? To al-Biruni, both the Holy Qur'an (God's word) and the cosmos (God's work) represent Divine Truth. Both can be apprehended in many different ways. To al-Biruni, 'understanding' includes 'understanding nature', which is in agreement with Qur'anic revelation, but not with (derivative) 'tradition'. Al-Biruni does not so much contrast science with theology as he contrasts science with (unthinking) tradition. But it has to be unadulterated science, just as it has to be unadulterated theology.

The Holy Qur'an and also previous revelations contain the Truth, which both true science and true scripture-based theology should proclaim, each by way of its own methodologies. History, however, teaches that this is not always the case. For example, in his extensive work on India, *Investigating India* (*Kitab tahqiq ma lil-Hind* – to be discussed in what follows), al-Biruni asserts that the *understanding* of the Holy Qur'an's eternal doctrines regarding the cosmos was in the past distorted by secessionist and heretical groups in the Islamic world (such as the Dualists/Manichaeans, *zanadiqa*, sing. *zindiq*). But India has also taught him that science is vulnerable to corruption when the scientists cave in and accept mass-held popular religious notions that contradict their own better knowledge, whence their scientific doctrines become disturbed and confused, 'in particular the doctrines of those authors – and they are the majority – who simply copy their predecessors, who take the bases of their science from tradition and do not make them objects of independent scientific research'. For these reasons, he deems Hindu science 'a mixture of pearls and dung'. This even includes the famed Indian mathematician and astronomer Brahmagupta himself (d. 665 CE), whom al-Biruni accuses of either caving in to the Brahmans, or perhaps merely mocking them, by lending his support to a position of 'imposture' in how to account for solar and lunar eclipses.

The gist of al-Biruni's message, then, is twofold: one, that science is a true form of comprehension of God's Creation; and two, that true and honest scientists are 'by knowledge' the 'more understanding' among God's servants. His is a call to arms in support of science as a religiously valorized but autonomous enterprise.

As Ahmad Dallal, Muzaffar Iqbal and many others have shown, it was the refusal on the part of the religious scholars of Islam to validate religious knowledge by way of 'proving' it through science that enabled them to vouchsafe the autonomy of the religious sciences. Their refusal to co-opt the ever-changing natural and human sciences to 'ascertain' the scripture's authority or miraculous authenticity meant that they succeeded in assigning each of the two cultural discourses a separate and autonomous realm of its own. This dichotomy also liberated the scientists from the threat of being censured by the religious authorities.

The Orientalist Challenge

In hindsight it appears that this state of a mutually energizing dichotomy of Islamic theological and

scientific discourses persisted until the colonization of the Muslim world by European powers, which was in full swing by the nineteenth century. For Muslims, the economic and political trauma of European colonialism came with the equally threatening onslaught of European cultural imperialism. The exploitative clash of civilizations generated deep changes in Muslim culture and self-perception, among them a new and apologetic trend in modern Muslim Qur'an exegesis that amounts to a valuation of the revelation by the standards of modern scientific discoveries. The phenomenon is both intra-Islamic and defensive. Not only was science ('the culture of reason and science') part of the self-proclaimed ideology of European superiority over an Islamic civilization that no longer had any science to offer, but Western Orientalists had also started to rewrite the history of Islamic science, stipulating an historical cultural cleavage between the Qur'anic ('Islamic') religious sciences and the rationalist and natural ('Foreign', largely Hellenism-derived) sciences that privileged the former at the latter's expense. This position found its most celebrated expression in a 1915 article by Ignaz Goldziher (d. 1921) titled 'Die Stellung der alten islamischen Orthodoxie zu den antiken Wissenschaften', published in 1981 by Merlin L. Swartz as 'The Attitude of Orthodox Islam toward the "Ancient Sciences"'. Goldziher and the many who have subscribed to his ideas maintained that a quite fatal rivalry existed between the representatives of these two separate and competing blocs of intellectual endeavours; inasmuch as the religious authorities consistently opposed scientific activities, the sciences in fact survived in spite of – and not because of – Islamic culture. In the end, and as a result of various political setbacks, the consolidation of an 'Islamic worldview' caused the rational sciences to stagnate as early as the eleventh century. During the past several decades, cultural historians and historians of science have systematically critiqued and largely discredited Goldziher's views, but general cultural histories of Islam as well as general histories of science still contain some version of his thesis.

Clearly, this Orientalist view of Islamic science was a transplant from a larger Eurocentric worldview grown of European Enlightenment roots that posits a systemic opposition between religion and science in medieval and postmedieval civilizations. A famous controversy on this issue occurred in the 1880s between the French Orientalist Ernest Renan (d. 1892) and the pan-Islamist activist Jamal al-Din al-Afghani (d. 1897), who lived in Paris at the time. It began with a lecture that Renan delivered at the Sorbonne in 1883, in which he maintained that Islam and science (and therefore, by implication, Islam and modern civilization) were not compatible; indeed, both the theologians and the theocratic rulers in all past Islamic societies had long stifled all activities pertaining to human reason and progress. Al-Afghani reposted that this model (paradigm) would at best be suitable to explain the workings of European (Catholic) civilization prior to the (Protestant) Reformation, but by its very nature the religion of Islam could encompass both faith and rationalism, as it had done for many centuries.

Today's scholars largely opine that the European model cannot be applied to Islamic civilization, or at least not in one fell swoop, since the evidence in authoritative religious writings on the merit of the rational sciences is scant, contradictory, and so far vastly underresearched. What can be said with certainty, however, is that productive, original scientific research persisted in the Islamic world well into the sixteenth century. But the double-edged ideological challenge of political imperialism and cultural Orientalism posed a dilemma for the Muslim intellectuals who, starting in the nineteenth century, embarked on the arduous project of devising philosophical blueprints and practical road maps toward religious reform and social and intellectual modernization within the boundaries of cultural authenticity. Sooner or later, the process inevitably involved the question of the very compatibility of science and Islam. Al-Afghani and many others before and after him reminded society of the illustrious history of past achievements by Muslim scientists and emphasized the proven compatibility of Islam and reason, hence also Islam and science. Others asserted that since Europe had learned its sciences from the books of Muslim teachers, the Islamic world was simply 'borrowing back' what the West had originally borrowed; by way of this historical argument, their position likewise asserted a fundamental harmony between the Qur'an and science.

The Qur'an and Science in a Nineteenth-century Qur'anic Interpretation

To illustrate the similarities and differences between a classical position on the issue, such as al-Razi's, and a nineteenth-century modernist reading, it may be useful to review Rashid Rida's exegesis of Sura

7:54 (the same verse that al-Razi had written about some 800 years earlier, quoted above). Rashid Rida (d. 1935) was a writer and journalist from a Syrian background who joined the inner circle of disciples around the famed Egyptian reformist theologian and jurist Muhammad Abduh (d. 1905). Their Qur'anic exegesis *Tafsir al-manar*, so named after Rida's journal and publishing house, was a joint Abduh-Rida enterprise until Abduh's death, by which time their exegesis had reached Sura 4; the *Tafsir* then continued as Rida's publication until Rida's death (at which time it had reached Sura 12). Like Abduh, Rida knew al-Razi's commentary well, and he quotes it on several occasions.

To Rida, as it had been to al-Razi, Sura 7:54 is a proclamation of the unity and omnipotence of God. Unlike al-Razi however, Rida was more deeply concerned with the problematic of the 'six days' as the time-frame of the stages of Creation, a process that the new cosmological theories of Western science of his time had pegged at billions of years. (Thanks largely to the Hubble Space Telescope, we today know that the sun's eight major planets [plus demoted Pluto] formed about 4.6 billion years ago.) Rida reminds us that these 'six days' of the revelation are 'God's days', each defined by what God has wraught or will work therein; 'a day with your Lord is like a thousand years' (Sura 22:47), and the Day of Judgement is 'a day whose measure is 50,000 years' (Sura 70:4). None of these 'days' are similar to those stretches of time measured in the 24 hours that we know, since our days have existed only since this earth was created, whence they cannot serve to measure Creation. To Rida, then, time is a mysterious entity that arrives with the beginning of Creation, but to his understanding time is not measurable in human terms (terms that are intelligible to humans) before the creation of earth, sun, moon and stars, those heavenly bodies that determine the measurable units of time on this earth.

In addition to the many Qur'anic verses that specify the 'six days' of Creation, Rida also quotes others that give a separate, more detailed timetable, such as Sura 41:9–12 (here condensed):

> (41:9): He created the earth in two days; (41:10): He placed on the earth firm-standing mountains above it, and blessed it, and measured on it its nourishment, in four days; (41:11): then He assumed the sky which [then] was [still a formless] smoke, and He said to it and to the earth: come here you two, willingly or unwillingly! they said: we come in obedience; (41:12): and He decided them as seven heavens [and created them] in two days, and for each He decided what was to happen in it, and the lower heaven We adorned with lamps and protection.

Rida well prefers the Qur'anic timetables of Creation over the more detailed and specific ones available in the Hadith of even the most authenticated collections, such as those of Muslim ibn Hajjaj (d. 875) and Ahmad ibn Hanbal (d. 855). According to the traditions, the creation of the soil occurred on Saturday, the mountains on Sunday, trees on Monday, objectionable things on Tuesday, light on Wednesday, animal life on Thursday and Adam, the first human being, in the evening hours of Friday. But to Rida, disciple and colleague of the modernist reformist Sheikh Muhammad Abduh, these and similar Creationist traditions are all by origin and nature Bible derived (that is, of *isra'iliyyat* provenance) and therefore largely untrustworthy.

Among the Qur'an's creational verses, Rida pays special attention to Sura 21:30: 'Do not the unbelievers see that the heavens and earth were a joined mass, and We clove them apart, and made every living thing from water, will they then not believe?' This 'joined/undifferentiated mass' was like 'smoke' or 'vapour'; Rida sees the link between this Qur'anic *ur-matter* and what the scientists of his age call 'nebula', a 'mass of particles' out of which, or so they maintain, the sun, stars and even the earth were shaped and then put in motion by the laws of gravitation. Rida's position on this parallelism of revelation and science is contradictory, meaning that he is far less comfortable in making the link between the two than was al-Razi. On the one hand, he accepts suitable findings of modern science as 'demonstration' of the Qur'anic text, as long as they are correct; if the science should turn out to be incorrect, this will not refute the truth of the revelation. On the other hand, Rida celebrates the revelation?science linkage as yet another proof of the Qur'an's wondrous nature, saying that it is among the proofs of the revelation's inimitability that it expounded truths that none among its first hearers would or could have known about. It also did so in language that did not confuse them, while later on a deeper understanding of the Qur'anic message would gradually be ascertained by humankind's intellectual progress. In consequence, on the basis of the Qur'anic revelation, some of the great scholars of Islam had previously thought about the same creational?cosmological issues over which the scholars of the Franks are now claiming a monopoly.

It is noteworthy that the creational details of Sura 7:54 take up most of Rida's exegesis of this verse.

The phrase ‘and then [He] assumed the Throne’ merely merits Rida's explication that this is a metaphorical expression and not to be understood literally. By contrast, the phrase ‘He covers up the day with the night which comes chasing it fast’ elicits a lengthy excursus, since to Rida this phrase means that the earth is round and is turning on its axis, so one half of it is in light and the other in darkness at various times, a fact that modern technology has proven but that Muslim scholars of both the ‘rationalist school’ (al-Ghazali [d. 1111] and al-Razi [d. 1210]) and the ‘traditionalist school’ (Ibn Taymiyya [d. 1328] and Ibn Qayyim al-Jawziyya [d. 1350]) had agreed upon a long time ago. (Actually, these scholars had merely agreed upon the earth's roundness, not its rotation around its own axis.) Rida then quotes Sura 39:5 on the Qur'anic images of the night ‘rolling up onto the day’ (as one rolls up a turban) ‘and the day rolling up onto the night’. Rida indicates that this Qur'anic notion of ‘rolling’ or ‘rotation’ of the earth could mean both that it revolves around its own axis and also that it rotates around the sun; many astronomers now subscribe to the latter theory, he says, but apparently he knew of no previous Muslim scientists whom he could quote on that issue. In spite of the occasional apologetic note toward the scientific discoveries of the modern age, quite lacking among his classical predecessors, Rida's focus both in his interpretation of Sura 7:54 and in his larger Qur'an-related work was to proclaim the unity and omnipotence of God. Science could provide ‘demonstration’ of revealed truths so long as its data were reliable. But in any case, the truth of revelation was independent of whatever science had to add or failed to add to its understanding.

Science as ‘Proof’ of Revelation

Eventually, the Abduh?Rida modernist position metamorphosed on its fringes into a new and now quite popular form of Qur'anic exegesis (largely written by nontheologians) that has defined the Qur'an’s miraculous nature by way of the miraculous conformity between Qur'anic statements and science, which then both implied the need to interpret the Qur'an in light of the findings of modern science and also made the Qur'an into an arbiter of the validity of scientific theories. The strategy, clearly a defensive reaction to the modern and largely Western-derived ‘culture of science’, is to manipulate Qur'anic verses so as to endow them with the latest scientific meaning. When science is employed to ‘authenticate’ scripturalist truth in this manner, Qur'anic insights are shown to predate Western scientific discoveries by a millennium and a half. In hindsight, this approach has been damaging (because limiting) to both the interpretation of scripture and the intellectual space entailed in the free pursuit of science.

By contrast, the Qur'anic scholars of the classical age, if they so chose, could refer to (often multiple) scientific explanations and theories about natural phenomena without employing the Qur'an’s authority in any of their support. Scripturalist interpretation and science were two different intellectual activities, the Qur'an’s was the autonomous repository of religious doctrine, and science involved the free pursuit of research and observation of God's Creation. On this scale, the nineteenth-century modernist scholars rode a precarious balance between past and future.

PART II

A MEDIEVAL CASE STUDY: COSMOLOGY, TECHNOLOGY AND FIVE EASTERN CALENDARS THROUGH AN ISLAMIC LENS

CHAPTER 4

THE MAKING OF A MEDIEVAL SCIENTIST'S CAREER:ABU AL-RAYHAN AL-BIRUNI

The Cultural Setting

The ancient Sumerian–Babylonian and Egyptian, the Roman, Jewish and Christian calendars were known at least in outline form to the scholars of classical Islam. As citizens of a vast intercultural empire that stretched from the Atlantic Ocean to central Asia, Muslim scholars also knew about other systems of time reckoning, such as the pre-Islamic Iranian civil calendar and the 'calendar of Alexander' (*Aera Alexandris*). The latter was of special interest to Muslim scholars studying Hellenistic documents, even though it is said to have come in three versions: one was instituted in Palestine at the beginning of the 27th year of Alexander the Great, king of Macedonia (329 BCE), another version began with the year following Alexander's death (322 BCE), while the most common form of this calendar, also known as the 'Seleucid' (or later also as the 'Ptolomean'), was initiated under one of his successors, the Macedonian general Seleucis Nicator, 11 and 12 years after Alexander the Great's death; he introduced this calendar in 312 BCE in the West and in 311 BCE in the East of the Seleucid Empire. In many of his studies on calendar events, al-Biruni preferred to use the 'Seleucid/Ptolomean' version of the 'calendar of Alexander' over the Hijra one (even when scrutinizing dates of events in the Prophet's own time). In his first great book on calendars written at the age of 27 (*The Chronology of Ancient Nations* [1000 CE]), he had initially misunderstood the calendar's identifying label when he ascribed it to Alexander the Great, king of Macedonia, rather than to the ruler Alexander IV (Aegus) whose death in 311 BCE was adopted as the epoch of this Seleucid chronography. Its designation by the name 'the era of Alexander' seems to be of late-Greek and Syriac origin; the Muslim scholars most probably adopted it from the Syrians, since the Syrian churches continued to use it long after the Seleucids were gone from Syria. Al-Biruni corrected this error in several later works, including his astronomic magnum opus, *The Canon Mas'udicus* (1031, written at the age of 58).

It takes a self-consciously expansive and actively global civilization to generate the interest and resources required for the study of 'alien' calendars. In its later, Gregorian cast, Dennis the Little's and the Venerable Bede's Christian Era, their 'AD system', has become the 'Common Era' and is close to being the global standard. We in the West are so used to having all manner of foreign chronographies translated into it, which our schoolbooks neatly record as BC (or BCE) or AD (or CE), that we fail to see the ingenuity and effort it took to coordinate and synchronize the disparate data. Today we use internet programs such as http://www.rabiah.com/convert/ or http://islamicity.org/ to find the exact Western equivalent of any date, past, present or future, in the Islamic calendar. In the more recent past, the Western colonial empires, especially England and France, were amply productive of calendric tables that provided the keys to the correlation of 'local dates' to 'Christian dates'. One such example, an academic exercise, is *The Muslim and Christian Calendars Being Tables for the Conversion of Muslim and Christian Dates from the Hijra to the Year AD 2000*; it was published in 1963 by G. S. P. Freeman-Grenville at the behest of the East African Swahili Committee that commissioned it to provide assistance 'for reasons of government and business' (i.e., government and business of the British Empire) in the face of 'the widespread local calendric confusion throughout East Africa'. The booklet begins with a quote from Psalm 89:13 ('teach us to number our days: that we may apply our hearts to wisdom'), a remnant of the sacralization of time but that by its biblical source and tenor surely also has an additional whiff of the British Empire about it.

Until cut short by the European expansion, the Islamic Empire was also in effect a global empire; Muslim governments ruled the world from central Asia to Spain for many centuries, a fact that undergirded the civilization's sense of self-reliance and enabled, or emboldened, many Muslim historians, geographers and astronomers to refer to calendars and chronographies other than their own. Even though the results of their labours were undoubtedly useful to their governments in many instances, Muslim scholars mainly engaged in the study of diverse systems of time management for the sake of advancement of science and knowledge, including knowledge of other peoples and their cultures.

Perhaps one of the most extraordinary features of this premodern Islamic cultural exploration was that it developed a full-fledged ethnographic dimension that in both geographic range and ethnographic detail went far beyond previous, similar, efforts on the part of the Greeks and Romans. The underlying theory of much of Islamic ethnology was to classify the peoples of the world by their scientific achievements, which in turn were deemed a function of their geographic location. High scientific achievement belonged to the peoples in the temperate latitudes, primarily the Indians, Persians, Chaldeans, Greeks, Romans, Egyptians, Arabs and Hebrews. People to the north of the temperate zone were white-skinned, sort of 'underdone', blond and slow; to its south they were sort of 'overcooked', black and foolish. Thus, the theory was climatic, its racism was environmental, not biological, and it had nothing to do with whether the people in question were Muslims. Even in this world-open cultural milieu, however, it still took a special, felicitous combination of scientific genius and cross-cultural sleuth to produce Abu al-Rayhan al-Biruni, medieval Islam's uncontested authority on time and timekeeping and a most thoughtful voice on the relationship between religion and science. (His full biography is presented in Chapter 5.)

Al-Biruni was a towering figure in medieval mathematics, astronomy and a raft of other sciences. He was a believing Muslim of the Sunni school who, mainly in his younger years, may have harboured some close and positive feelings for the Shi'a tradition (though not its esoteric fringes). He did not belong to any specific legal or ideological school, nor did he follow the teachings of any specific religious authorities. His piety as a Muslim was grounded in his own active understanding of Qur'anic monotheism and its ethics. Al-Biruni was a self-taught cultural historian of nations and religions well beyond the pale of most of his contemporaries, especially as regarded the manners and customs, doctrines and rituals, sciences and cosmologies of India. He was an avid student of the Greek masters – Euclid, Aristotle, Apollonius, Ptolemy – whose works he committed to memory, and a polyglot who spoke his native Khwarizmian (an Iranian language), Persian, Arabic, Sanskrit and Turkish, wrote in Arabic and Persian and read Syriac, Greek, Hebrew and Sanskrit. Some say that his reading and writing skills in Sanskrit were less than excellent, even though he is known to have translated Euclid's *Elements*, Ptolemy's *Almagest* and his own book on the astrolabe from Arabic into Sanskrit in order to acquaint Indian scholars with the Greek and Arabic scientific traditions. He also translated the *Yoga Sutras* (Hindu metaphysics) of Patanjali (first century CE) from the Sanskrit into Arabic.

His biography takes us to eastern Iran and Central Asia at the end of the fourth century of the Islamic calendar, that is, the end of the tenth century CE of the Common Era. By al-Biruni's time, the political map of the once-united Islamic world had profoundly changed. The Abbasid caliphate in Baghdad had lost control over all parts of its former realm with the exception of Iraq, crown colony of the Abbasid dynasty and site of their famed capital. Yet even Iraq and Baghdad had been invaded by an Iranian Shi'ite (Daylami) dynasty of soldiers from the Caspian region, the Buyids (or Buwayhids) who from 945 to 1055 ruled Iraq, where they virtually held the Abbasid caliph their prisoner; other branches of their family also controlled several Iranian provinces for a time. Everywhere else, local dynasties or foreign invaders had established autonomous governments who – if they so chose – could request documents of investiture from the caliph in Baghdad to bolster their legitimacy. The eastern parts of the empire were especially prone to civil wars and invasions from abroad. While life was arguably difficult for most who lived in eastern Iran and Central Asia in the late tenth and early eleventh centuries CE, al-Biruni's troubles were aggravated by two factors: first, that his work (or at least his bigger projects) required royal patronage for funding, and second, that he had talents that were of interest both to competing local rulers and to the foreign invaders.

Yet these politically turbulent decades and centuries also marked a high point of intellectual achievement in the whole Islamic realm. The legacy of late antiquity had been absorbed and had catalyzed the rise of a more ecumenical and broader-based intellectual Islamic culture that fused the classics of pagan and Christian Hellenism with the legacy of Mesopotamian, Iranian, Indian and Chinese scholarship and included the arts and learning of Jews and Christians, Zoroastrians,

Manichaeans, Hindus and Buddhists. That the tenth and eleventh centuries CE were a high point in Islamic natural science and philosophy was largely due to the richness of available educational resources in the Islamic world. Their bulk was rooted in knowledge imported across civilizational lines. By al-Biruni's time these resources (and their study) were not institutionalized in the Greek and Hellenistic manner, such as by way of academies and organized faculties, but had come to exist in the form of widely-dispersed princely and other personal libraries, some of which were far away from Islam's 'heartland'. Princely and other private courts were often also research centres, and the scientists who worked there were often connected by webs of direct or indirect tutorships. That even provincial and largely self-taught students like al-Biruni in Khwarizm and his Iranian contemporary Ibn Sina (Avicenna) in Bukhara could absorb the 'learning of the ancients' at that time was, of course, due to more than the ambitions of regional potentates bent on gathering libraries to signal dynastic sophistication. Arabic had become the language of learning and high culture, not only in the Arabic-speaking world but throughout the Islamic realm, where it played a role quite similar to that of Latin in the western and Greek in the eastern regions of medieval Europe.

Many Muslim scholars, especially in the natural sciences and philosophy, owed their felicitous connection with the ancient texts to the gigantic translation movement undertaken by pioneer Arabic-speaking scholars of the late eighth and ninth centuries in West Asia (mainly Syria and Iraq), whose activities had been sponsored by the Abbasid caliphs in Baghdad. Indian scholars (and Indian textbooks conveyed by Indian diplomatic delegations) had participated in the scholarly mix in Baghdad under the caliph al-Mansur (d. 775 CE) by contributing important data and ideas on Indian science, especially mathematics and astronomy, such as the Indian sine function in trigonometry in place of the cumbersome chords of arc used in Greek astronomy. Perhaps partly through trade routes, Greek astronomy had begun to make its presence felt in India as early as the third and fourth centuries CE. There is some evidence that the Greek scientist Hipparchus in Alexandria, Egypt (second century BCE), had employed some aspects of spherical trigonometry in his astronomical calculations; its use later gained much greater importance in the work of Ptolemy (second century CE). But (in the words of Glen Van Brummelen) the spark for trigonometry in India had come by way of some pre-Ptolemaic version of Greek mathematical astronomy, and therefore in both content and method Indian trigonometry became something quite distinct from the Greek heritage.

History – or is it mythology? – relates that an Indian diplomatic delegation arrived in Abbasid caliph al-Mansur's Baghdad in 773 CE that included the (otherwise unknown) astronomer Kanaka, himself supposedly an expert on eclipses, who was bearing the gift of a small library of Indian astronomical texts for the caliph. Among the texts were versions of the *Siddhantas* (*Systems of Astronomy*) by the late-fourth- and early-fifth-century CE Indian astronomer Aryabhata and works of the seventh-century astronomer and mathematician Brahmagupta (d. 668 CE). It is reported that al-Mansur immediately ordered their translation into Arabic and their compilation into a textbook, which then became known as the *Great Sindhind* (*Sindhind* being the Arabicized form of the Sanskrit word *Siddhanta*). According to others, two Muslim astronomers, Ibrahim al-Fazari and Ya'qub ibn Tariq, translated an eighth-century Indian astronomical work known as *Zij al-Sindhind* (*Astronomical Tables*) into Arabic after 770 CE, under the supervision of an Indian astronomer visiting al-Mansur's court at that time.

But the bulk of what was to become a gigantic Islamic intellectual enterprise had Hellenistic roots. The Abbasid caliph Harun al-Rashid (d. 809 CE), patron of the first great research library (called the House of Wisdom, *Bayt al-Hikma*) and the first teaching hospital in Baghdad, supported the collection and translation of foreign philosophical and scientific texts from both East and West. The first golden age of scientific research and production however, only fully arrived during the reign of his younger son the caliph al-Ma'mun (d. 833 CE), whose vision was to base his rule on a new (elitist and antitraditionalist) political and cultural foundation. Part of his policy to institutionalize rationalism was to create a centre of learning, free enquiry and invention.

Al-Ma'mun expanded his father's research library into the famed research centre in 830. It is widely thought that he had been inspired to do so by an academy in Jundishapur (site of present-day Shahabad in Khuzistan Province, south western Iran), which the Persian ruler Khosrow Anushirwan I (d. 579 CE), or even one of his third- or fourth-century Sassanian ancestors, had established by imperial decree to gather Greek, Roman, Byzantine, Indian and Far Eastern knowledge as resources for Iranian scholarship. Working languages at this institution are said to have been Greek and Syriac, while Pahlavi (middle Persian) was the language of the court. George Saliba and others have questioned the reliability of reports on Jundishapur as a pre-Islamic centre of medical and scientific

knowledge in Iran that carried over from late antiquity into the Abbasid period (since the tradition, if indeed it existed, had lain dormant during the Umayyad period).

An Arab army had conquered Jundishapur in 638 CE. Two hundred years later, the Abbasid caliph al-Ma'mun, following the example of his father, Harun al-Rashid, created his own version of the House of Wisdom in Baghdad that is said to have been all of the following and more: think tank and academy, university, library and translation centre, archive and laboratory, observatory and hospital, intellectuals' club and scholars' living quarters for the world's finest scholars for several generations. The residents and associates produced advanced research in a variety of fields, with each scholar as a rule engaged in more than one discipline: algebra, trigonometry, geometry, engineering, physics, astronomy, biology, medicine, pharmacology, rhetoric and logic, literature, metaphysics and theology. Financially supported by the ruler (elsewhere also by administrators, professionals or rich scientists like the ninth-century Banu Musa in Damascus), Muslim scholars translated and decoded, interpreted or developed and transformed works by the great masters of Greek science and philosophy: Euclid, Pythagoras, Archimedes, Apollonius, Ptolemy, Socrates, Plato, Aristotle and many others. The House of Wisdom was as significant an institution as the research centre at Jundishapur founded by the Sassanians in Iran 200 years earlier and the museum founded by the Ptolemies in Alexandria 1,000 years before. In Baghdad the Muslim scholars pursued their studies in an environment of intellectual freedom. By acknowledging that they aimed to decode the mysteries of God's Creation, even though they were helped with theories that often had their origin in pagan minds, the Muslim scientists could do their research reverently but freely, without the need to force their scientific work to fit a preconceived notion of the universe dictated by theology.

Harun al-Rashid and al-Ma'mun had sent teams of scholars across the political frontier to Byzantium to search out manuscripts. There is even a story that, after defeating a Byzantine emperor in battle, al-Ma'mun's request for tribute specified his desire to obtain a copy of the *Almagest*, an astronomical masterpiece by the second-century CE Hellenistic astronomer Ptolemy. Other texts were found in Monophysite and Nestorian Christian monasteries in Abbasid-controlled Syria and Iraq, while the intellectual traditions of Hellenistic pagan Harran in Syria, Hellenistic Christianized Alexandria in Egypt and Zoroastrian Hellenized Jundishapur in Iran added both manuscripts and in some cases also knowledgeable scientists to the mix who would serve as translators. The early generation of scientist-translators was soon followed by schools of editors and exegetes who glossed and polished the new texts. ‘Translation’ meant the need to observe, identify and certify, weigh and measure, critique, doubt, prove or disprove, improve or replace; in this manner, Arabic-Islamic science became an empirical (rather than a contemplative) enterprise that generated both new theories and concepts and also entirely new disciplines.

The ethnic backgrounds of scientists working in ‘Arabic science’ varied widely; some hailed from the centrally located provinces in the Arab world, but many others were increasingly of Iranian or Central Asian, North African or Iberian backgrounds. What united them was their use of the Arabic language in their professional lives. After the rise of the Abbasid state in 750 CE, the term *Arab* had become a cultural and civilizational term. Medieval scientists, and other intellectuals and artists in other disciplines, are therefore often identified as ‘Arab’ or ‘Arabic’ scholars in order to transcend geographic, ethnic or religious identification, since their ranks included Jewish, Christian and Muslim individuals. It is perhaps questionable whether the scholars and poets themselves would always have been happy with the ‘Arab’ or even ‘Arabic’ label, most especially so in the eastern region of the Islamic world where Iranian politics, culture and the Persian language had staged a comeback by the end of the tenth century. In today's academic literature, the terms have largely prevailed, and writers and scholars of whatever ethnic background who used the Arabic language as the medium of their cultural production are referred to as ‘Arabic’ scholars. Modern nationalisms, especially outside the Arab world, in contrast, are pushing hard to discontinue this usage. Thus, al-Biruni is now proudly celebrated as a cultural icon of ‘our nation's past’ by Arabs, Iranians and Uzbeks (and perhaps some others).

Al-Biruni's Cosmology and its Sources

In Chapter 3 on the Qur'an and science, I presented the example of a famed theologian's Qur'anic exegesis on the creation and workings of the cosmos: Fakhr al-Din al-Razi's (d. 1210) interpretation of the Qur'an 7:54. The theologian al-Razi lived about 150 years after the century and a half after the

scientist al-Biruni (d. *c*. 1050). It is noteworthy that much of al-Razi's cosmological 'examples' in this scripturalist exegesis were informed by his familiarity with at least the outlines of classical astronomical theories, a fact that shows the degree to which scientific culture had filtered into society and the extent to which it had become available to members of the educated elite.

Here follows a brief summary of some of the theories of classical cosmology that historically informed the work of Arabic-Islamic scientists, including al-Biruni. Astronomy was then divided into two distinct areas: planetary astronomy and the astronomy of the daily motion of the heavenly vault or great outer orb, that is, the greater celestial sphere of fixed stars. Medieval Islamic astronomers largely followed their Greek sources. As outlined above, the first contact with Greek science had sometimes come by way of Syriac translations that were then translated into Arabic or – later – Arabic translations made directly from the Greek. Also available were Greek astronomical ideas blended with Babylonian procedures and some profound Indian influences: a cross-cultural and intercultural mix that had occurred during the Achaemenid and Seleucid periods of Persian history. In the end, it was the Greek, and especially Ptolemy's, astronomy that won out as their primary source.

Ptolemy's astronomy had derived from a long line of Greek scientists that included Thales of Miletus (d. 546 BCE), who wrote on the substance of the universe, and Plato (d. 347 BCE) and Aristotle (d. 322 BCE), who envisioned seven planets (Moon, Mercury, Venus, Sun, Mars, Jupiter and Saturn) mounted on seven solid, individual spheres around the Earth. Though contested among the scientists, the order of the planets' spheres, counted from the Earth, was determined by the scientifically observable orbital time of each body (based on the sequence of planetary ascents) as seen from Earth, where the fastest orbits were reckoned to be closer in and the slower ones farther out. These planetary spheres, each nestled within the other, were spinning from East to West within an eighth, or the greater, or the 'highest', orb of the fixed stars that rotated from West to East. The impetus for motion came from a divine force exterior to the network of the spheres. Some Islamic philosophers even accepted the Greek notion of a ninth, or 'universal', sphere without stars that is girdled with the invisible Zodiac; this invisible ninth sphere is Ptolemy's *Primum Mobile*, 'the First Movable' or 'Prime Mover' that gives motion to all others. The philosophers Ibn Sina (d. 1036) and Ibn Tufayl (d. 1185) accepted it, while the theologian al-Razi (whose Qur'an-based cosmology found scripturalist proof for eight spheres only) did not. Others, such as the mathematical astronomer al-Biruni, appear not to have worried about it.

The aim of the Greek scientists was to discover the structure and arrangement of the universe as a whole. Parts of their task (which required astronomical observation and geometry) led to 'concrete' results – such as measurements of the size of the earth and distance between Earth and the moon. Some other parts of their task could not proceed unless astronomical observation and geometry were supplemented by a set of physical assumptions. We cannot know from astronomical observation whether the sun goes around the Earth or the Earth goes around the sun. Similarly, we cannot know whether the observed motion of the sun results from an eccentric cycle or from an epicycle. We must base our astronomy on physical hypotheses, which are the results of physical or philosophical enquiry.

Aristotle's god is a Theoretician who initiates creation by contemplating perfection – that is, himself. By analogy, the Aristotelian physicist is an observer who contemplates nature, and nature is a cosmos of eternal forms. According to Aristotle, the heaven is changeless because it is physically impossible for it to be otherwise. Heaven is made of the ether whose essence is absolute changelessness and whose motion is circular around the centre. Classical Greek assumptions about the cosmos, most famously formulated by Aristotle in his *On the Heavens*, were that, first, the sun's orbit is a circle; second, the sun's orbit is centred on the earth; and third, the sun travels on its orbit at constant speed. Today we know that all three of these assumptions are false, in that the solar orbit is an ellipse, centred at one of the ellipse's two foci, and that the sun's speed on this ellipse is not constant. Yet even Aristotle had raised the number of celestial spheres to better account for the planets' observable deviations from circular paths. Based on their own observations and mathematics, Greek astronomers such as Apollonius (d. *c*. 225 BCE), Hipparchus (second century BCE) and Ptolemy (d. *c*. 178 CE) were capable of modifying – if not quite abandoning – Aristotle's physics whenever it seemed expedient. By the time that Ptolemy had codified Greek astronomy, the solid-sphere cosmology of classical Greek science with its seven material orbs had been augmented by adding 'epicycles' and 'deferents', smaller circles required to account for observed complexities of planetary motion.

The primary source of astronomical knowledge and calculations for al-Biruni, as for most other

medieval Arabic and Islamic astronomers, was the second-century CE Hellenistic philosopher and scientist Claudius Ptolemy of Alexandria (d. *c*.178 CE). Ptolemy was a brilliant applied mathematician who also wrote on geography and optics and astrology, but his fame rests mainly on his work as an astronomer. For practical computing, Ptolemy's *Handy Tables* served all later astronomers as a prototype, while their cosmology was largely based on Ptolemy's *Planetary Hypotheses*. Most influential however, was Ptolemy's work on planetary theory originally called something like *The Thirteen Books of the Mathematical Composition of Claudius Ptolemy*; later it was known by the title *Megale Syntaxis*, the '*Great Composition*'. The Greek superlative of *megale* ('great') is *megiste* ('greatest'). When the work was translated into Arabic, they called it *Al-megiste*, later fashioned by Latin writers into *Almagest*. Starting with the reign of Harun al-Rashid at the end of the eighth and beginning of the ninth centuries, the book became available in Arabic by way of numerous translations, summaries and commentaries, such as al-Farghani's popular summary of 830 CE; by the ninth century, the Arabic astronomers had begun to correct Ptolemy's data and to critique Ptolemy's theories.

Al-Biruni's cosmological model remained wedded to Ptolemy's planetary theory that the earth and heavens are spherical and the earth is at the centre and stationary. The main feature that made this model workable for al-Biruni, as it had for Ptolemy and his school, was that the earth is round. In the extensive discussion of Hindu cosmology that he presented in his book on India, discussed in Chapter 5, al-Biruni supported the Indian astronomer Brahmagupta's theories of the sphericity of the heavens, the rotundity of the earth at their centre, the pull of gravitation in its northern and southern halves and the like, by defining them as 'proven elements of astronomy as contained in the first chapter of Ptolemy's *Almagest*'. Proof of truth of an Indian theory, in other words, for al-Biruni lay in its agreement with the Greek. If, on the other hand, Indian astronomy had a feature that Greek astronomy did not, al-Biruni cited and critiqued it on its own merits. For example, reporting on the different Hindu debates regarding the rotation of the earth (see below and Chapter 5), al-Biruni concludes that regardless of its direction or whether it rotates or is at rest, 'the rotation of the earth does in no way impair the value of astronomy, as all appearances of an astronomic character can quite as well be explained according to this theory as to the other'. When discussing an astrolabe designed by his contemporary Abu Sa'id Ahmad al-Sijzi (d. 1024), who reckoned that the apparent daily rotation of the celestial spheres results from the motion of the earth rather than of the celestial spheres themselves, al-Biruni remarks that although the motion of the earth is quite possible, this problem is of concern to natural philosophers but not to mathematicians like himself. Nevertheless, he authored (at least) one special monograph on the issue, listed in M. Kamiar's *Bio-Bibliography for al-Biruni* under the title *Book on the Fixed Position of the Earth or its Movement* (*Kitab fi sukun al-ard aw harakatiha*), but this text has been lost.

From among the many problems that occupied astronomers' attention, we have here selected three to illustrate both continuity and change in the transmission of knowledge from the 'ancients' to the Arabic-Islamic scientists: the solar ecliptic, precession and heliocentrism.

The Ecliptic

In our heliocentric universe, the ecliptic defines a great circle in the celestial sphere, and the sun appears to move along it as the earth moves in the orbit of the sun. The two great circles in the celestial sphere, the ecliptic and the equator, are inclined at an angle of almost 23.5° (23 arc minutes and 26 arc seconds), which is known as the obliquity of the ecliptic. In premodern geocentric cosmology, both the seasons and the changes in star visibility at different times of the year from any specific location on earth were attributed to the fact that the sun's yearly motion along a single circle around the earth is oblique (slanted) with respect to the plane of the celestial equator. The two great circles in the celestial sphere, the ecliptic and the equator, intersect at two points, called the equinoxes (when day and night hours are of the same duration). The concept of the ecliptic as inclined solar path was formulated in Babylonian astronomy in the seventh century BCE. Its discovery in Greece is dated into the fifth century BCE. The Babylonians had calculated the solar ecliptic at 24° (or, according to Euclid in 300 BCE, as 1/15 of a circle), and Ptolemy had similarly defined it as just a smidgen shorter: 23 arc minutes, 51 seconds, and 23 nanoseconds. Ptolemy had calculated the inclination of the solar ecliptic by geometric methods. The Syrian astronomer al-Battani (d. 929 CE) calculated it using trigonometry. The Central Asian astronomer al-Khujandi (d. 1000 CE), with whom al-Biruni worked and studied in Iran for a while, had even constructed a gigantic astronomical device, a mural sextant, for his observatory on a mountaintop above Rayy to measure sunlight angles (a series of meridian transits of the sun) for the same purpose.

Precession

In a geocentric universe, precession is the slow revolution of the whole field of stars from West to East, parallel to the ecliptic. The rate is slow (1˚, or arc minute, in 72 years, or 50 arc seconds per year), but over the centuries and millennia the change is noticeable. Today the 12 zodiacal signs – Aries, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpio, Sagittarius, Capricorn, Aquarius and Pisces – and the 12 constellations that carry their names no longer coincide, as they did in antiquity. Even the medieval astronomers were aware of a good measure of 'slippage' between the two. The astronomers were also aware that the equinoctial points on the solar path were moving slowly westward from the constellations where they were once observed. This movement of the vernal and autumnal points on the (invisible) solar ecliptic is called the 'precession of the equinoxes', and to the classical astronomers it appeared that the stars were being shoved from their place by that mysterious outer sphere that lies beyond the seven planetary spheres. It is only thanks to Newton's laws of gravity formulated in the eighteenth century CE that we now know that the precession of the equinoxes is caused by a 'wobble' in the earth's axis of rotation due to the gravitational attraction of the sun and moon on the bulge of matter at the earth's equator.

Precession was discovered around 130 BCE by Hipparchus, one of the famed librarians of the ancient Library of Alexandria, on the basis of a predecessor's data gathered around 280 BCE. It was firmed up and elaborated upon by Ptolemy 260 years later (when he compared Hipparchus's observation of the motion of fixed stars within and outside of the zodiac with his own). Ptolemy also presented the evidence that the axis of the precession passes through the poles of the ecliptic: since the motion is parallel to the ecliptic, the stars shift northward and southward with respect to the equator. Because of an imprecision in the older data, Ptolemy misjudged the rate of precession, putting it at 1˚ in 100 years instead of 1˚ in 72 years. When, therefore, the Islamic theologian al-Razi (d. 1210) in his exegesis of Qur'an 7:54, presented above, quoted the figure of 36,000 years for one complete cycle of equinoctial precession, he was clearly doing so under the influence of old Ptolemeic data. By the ninth century CE, Arabic-Islamic astronomy had refined and expanded the functions of trigonometry. Thus, when the astronomer al-Battani (d. 929) worked on the phenomenon, he adopted a uniform precession of 1˚ in 66 years, while al-Biruni's immediate predecessor, Ibn Yunus (d. 1009), adopted a uniform rate of 1˚ in 70 years, which may be the most accurate medieval value for the precession; it puts the number of years required for one complete cycle of equinoctial precession – as the earth pirouettes around a point in the sky near the Pole Star – at 25,700 years, very close to today's calculation of 25,784 years.

Heliocentrism

There are indications that some Muslim astronomers, including al-Biruni, entertained the possibilities that the earth is not stationary but spins around its own axis, and that the universe is not geocentric but heliocentric. In the end, their professed system remained geocentric. Surely, this was in part due to the scholars' deference to Aristotle and Ptolemy, who had taught a geocentric cosmos. In part it may also have been occasioned by the demands of astrology, a quite popular medieval science that was based on geocentrism. In addition, with the available technologies that lacked the telescope, heliocentrism could not be demonstrated irrefutably, nor could it be of any use in practical astronomy. Even a stationary Earth around which the sun, planets and stars were (as we now know 'apparently') spinning in an East-to-West motion served classical and medieval astronomers as a basis for increasingly precise calculations of global arcs of latitude, longitude, time zones and the like. In Islamic astronomy, however, the arguments for or against the earth's rotation were part of a purely scientific discourse removed from theological considerations. When European astronomers in the sixteenth and seventeenth centuries CE replaced this geocentric model of the universe with the heliocentric one, the shift did not undo the fundamental validity of the astronomical data of premodern science, but placed them in a new context.

New Technologies

While al-Biruni's work was grounded in the rethinking, critiquing, 'doubting' and 'rewriting' of the classical authorities, he was also the beneficiary of a number of new technologies that had become available in the Islamic world prior to his time. Muslim merchants and scientists, rulers,

administrators and tax collectors, men of letters and their reading public had access to these new or newly-improved technologies that were important factors in the economic and cultural florescence of their world. Three examples may suffice here: the Indian and Arabic numerals, the astrolabe and paper.

Numerals: The History of the Indian Numerals, How the Arabs Obtained the Zero and What it Did to their Mathematics

A symbol used to represent a number is called a numeral. The ancient Sumerian and Babylonian number system was like an abacus inscribed symbolically onto a clay tablet, where a numeral typically derived its value from its position in a number system that was sexagesimal (based on the number 60). (This sexagesimal number system survived by remaining the standard of later astronomical reckoning. It is therefore also still with us today as an organizing principle in our geometry and our measuring of time.) The Babylonians used only two marks to represent their numbers: a wedge that represented one (the unit symbol) and a double wedge that represented ten (the ten symbol). When representing a number that was 60 or a multiple of 60, the Babylonians eventually started to use an additional symbol, beyond the unit symbol and the ten symbol, that is, a positional null or zero, to denote an empty space. This 'zero', however, was only a placeholder that did little more than ensure that all digits fell in the right places. Zero was a digit, not a number. Zero took its meaning only from the digits to its left; in itself, it had no value.

It was the Indian mathematicians who transformed the zero from placeholder to number. In Charles Seife's Buddhism-inspired words, 'this reincarnation was what gave zero its power'. This numerical 'reincarnation' occurred sometime during or after the fifth century CE, after the Indians had whittled down the many numerals of their own previous (Brahmi) decimal number system to nine and had also adopted a Babylonian-style place-value system, except that their numbers were still base ten, instead of base 60. If a number lacked a digit, the Indians indicated this by putting a dot or small circle, in Sanskrit: *sunya*, 'empty'. The Arabs would later continue the practise and turn this word into Arabic *sifr*, while Western scholars thrice removed would eventually render it as *zephirus* or *cifra* or *cipher*. This system of numbering allowed the Indians to add, subtract, multiply and divide numbers swiftly and without using an abacus. But the true impact of the Indian numbers, and especially the zero, was much deeper. As the Indians transformed the zero from mere placeholder to number, numbers gained independence from their (Greek-propagated) geometric significance that was always reducible to a physical reality. The new 'abstract' quality in the Indian numbers was the beginning of algebra. In this system, negative numbers made sense, as did mathematical operations that involved the zero, sometimes with pretty unexpected and radical results: multiply by zero, the result is zero; divide by zero, and the result is infinity.

And so the Arabs borrowed and adapted not only the Indian numerical system but also the Indian numerals. The older, indigenous Arab system of writing numbers had been 'alphanumerical', since it was based on the 28 letters of the Arabic alphabet (arranged in a different sequence), where each letter sign had a numerical value. By the first four signs in the sequence, *alif*, *ba'*, *jim* and *dal*, the system was known as *abjad* notation. This system continued in everyday use even after the Indian numerals had been adopted by the scientists; some scientists, such as al-Biruni, used both systems simultaneously. Today a few merchants and a few scholars are still familiar with it, but even their small group appears to be shrinking. The original *abjad* system did not contain the zero.

There is no question that the Arabic scientists learned the nine-digital number system and the zero from the Indians; it is also most likely that this process of transmission occurred in Baghdad during the early ninth century CE. Histories place this dramatic event in the caliph al-Ma'mun's House of Wisdom and focus on two *dramatis personae*, one dead at the time and one living, as well as several book manuscripts, one an Indian original that became available to the Arabic scientist but was thereafter lost, the other its Arabic translation that would eventually also be lost and survive only in a Latin translation done centuries later. The dead scientist in this story is the seventh-century Indian mathematician and astronomer Brahmagupta (d. 668 CE), author of *Brahma Sphuta Siddhanta* (*Opening of the Universe*). The living scientist is Abu Ja'far Muhammad ibn Musa al-Khwarizmi (b. *c*. 780, d. *c*. 850 CE) who hailed from the oasis of Khiva in Khwarizm, now Khorasan Province, Uzbekistan. His birthplace was an important stop on the Silk Road and quite an intercultural place; his family background may have been Zoroastrian or possibly Jewish. At a young age he garnered the reputation of a master mathematician and astronomer and was summoned by the caliph al-Ma'mun to join the

faculty of the House of Wisdom. There he heard about Brahmagupta's work and that it had probably been used a few generations back by an Indian astronomer (perhaps the enigmatic Kanaka mentioned above?) who had worked in Baghdad at the court of the caliph al-Mansur. Al-Khwarizmi then searched for the book and found it and had it translated into Arabic under the title of *Sindhind*. If this story is true, this would have been the second Arabic translation of a title Arabicized as the *Sindhind*, the first one having been commissioned by the caliph al-Mansur himself, a generation earlier.

It was in this book that al-Khwarizmi is said to have learned about the zero. For Indian mathematicians, the zero was the source code behind higher mathematics, including astronomy. Al-Khwarizmi and his colleagues followed suit, basing their theories and calculations on a rereading of Indian but also Greek, Iranian and Hellenistic authorities, such as Ptolemy. They strove to design a new map of Earth and sky that measured location and time using the positions of Earth, sun, moon and stars, recording *zij* (star charts), calculating latitudes and longitudes, the direction toward Mecca, prayer times, the first lunar crescent visibility and other events of the calendar.

By embracing the zero and thereby the abstract quality of numbers, al-Khwarizmi and others of his generation came to view mathematics as a means to decode the mysteries of the universe. Numbers could provide a key to the complexity of God's Creation; placing the zero at the centre of a great 'mathematization' of the universe, they employed the new Hindu mathematics to map ever more complicated and abstract processes. To move the 'source' of mathematics from the physical into the purely abstract also meant to discover the algebraic quality of numbers.

Al-Khwarizmi wrote on mathematics, astronomy, geography, sundials, the astrolabe and the Jewish calendar. Among his books that remained on the required reading lists of universities in Europe and the Muslim world until the sixteenth century and beyond, arguably the best-known title was a handbook on algebraic calculations entitled *Book of Calculation of Integration and Equation* (*Kitab hisab al-jabr wal-muqabala*), also quoted as *The Compendius Book on Calculation by Completion and Balancing*. The treatise began with an exposition of second-degree quadratic equations, discussed algebraic multiplication and division, followed by numerical measurement of surfaces, the division of estates and other legal questions; all of these problems were presented in the form of numerical examples. All in all it was a practical work that listed more than 800 problems of arithmetic and gave their step-by-step solutions. By virtue of this book, al-Khwarizmi is considered the 'father of algebra'. They say that what really motivated him to develop the rules of algebra was the desire to find a better way to manage the Qur'an complicated inheritance laws (such as the laws listed in Sura 4:11 and 4:12) that determine in detail the shares due each heir depending on their relationship to the testator or testatrix; the scripture specifies each share in terms of fractions. Algebra was furthermore a most useful tool in the measuring and division of lands, the digging of canals and many other practical tasks. Finally, al-Khwarizmi (in another of his mathematical personae) is also the namesake of the term *algorithm*, because he authored a similarly important textbook (now lost but probably entitled *Book of Reckoning with Indian Numerals* [*Kitab hisab al-'adad al-Hindi*]) in which he taught the 'new math' that came with the 'new numerals'. At his time and until the fifteenth century, the term *algorithm* was synonymous with positional numeration. Today the term *algorithm* applies to any mathematical procedure consisting of an indefinite number of steps, each step applying to the one preceding it. (Here it may be worth remembering that Europe adopted the Indian numerals from, or by way of, the Arabic mathematicians, whence we call them Arabic numerals. Pope Sylvester II, the first French pope [d. 1003], ordered that the church replace the cumbersome Roman numeral system with the much more efficient 'Arabic' decimal place-value numeration. In a largely illiterate Europe mired in feudalist poverty, this papal order did not take hold until a good three or more centuries later.)

Technologies for Scientific and Popular Use: The Astrolabe and the Sundial

The Astrolabe. An astrolabe is a two-dimensional model of the celestial sphere. Effectively, it is an analogue calculator, a predigital analogue computer capable of working out several different kinds of problems in spherical astronomy. (There are four types of astrolabes, of which the most common is the planispheric astrolabe.) Astrolabes were invented in antiquity; the theory of stereographic projection (the mathematical means of representing the three-dimensional sky onto a two-dimensional plate) has been traced back to the Hellenistic astronomer Hipparchus (d. *c*. 120 BCE), and the very word *astrolabe* is said to come from the Arabic version of a Greek term meaning something like 'star holder' or 'star taker' or 'the one who catches the heavenly bodies'. At the hands of Arabic-Islamic

scientists, their design and function grew increasingly complex, as new features were added.

An astrolabe is relatively easy to use, but the mathematics behind it are quite complicated. Timekeepers, astronomers and astrologers made extensive use of the astrolabe; many, including al-Biruni, also wrote theoretical and technical tracts and manuals about the instrument and are known to have constructed ever more modern and more accurate versions of it. Before the end of the thirteenth century, astrolabes had come into use from India to Islamic Spain and from the tropics to Scandinavia; astronomers and surveyors in places like Italy and England are known to have used them until the eighteenth century. Surely, they were the high-tech item on the market for a large variety of consumers for a long period of time. What was the connotation of the word *astrolabe* in medieval European parlance? One wonders why in the twelfth century a couple of intellectuals like Abelard and Eloise named their child Astrolabe. Was that name suitable because of its distance from the church (since it was not a saint's name), or did it stand for ‘technological and cultural advancement’, ‘key to the wonders of the cosmos’ or ‘source of astonishment and amusement’, or was it just something ‘fashionable’? Some years back the actress Gwyneth Paltrow named her daughter ‘Apple’; the PR message at the time seemed to focus on the healthy fruit connoted by the name; so as far as we know, the actress may not have been thinking of Steve Jobs' computer. In 1391 or 1392, the prominent English courtier and poet Geoffrey Chaucer (d. 1400), author of *The Canterbury Tales*, wrote a formal English work, *Treatise on the Astrolabe*, that he cast in the form of a private instruction manual for his ten-year-old son or godson, Lewis; historians of literature and science have thoroughly scrutinized both the book and its personalized prologue and opine that the tract was most probably not written for a child, even a precocious one, but was meant for a more general audience of both student readers and nonacademic practitioners. It appears that to know about the astrolabe was part of being a literate individual.

Astrolabes were devices that measured the position of celestial objects for a specific location, that is, they were used to find the angle of sun, moon, planets or stars above the horizon or from the zenith. By enabling the astronomer to work out the position of the sun and principal stars with respect to the local meridian as well as the local horizon, the astrolabe allowed him to find his geographical latitude and the direction of true North (even by day, when the stars were not visible). Astrolabes were used to determine the *qibla* (direction toward the Ka'ba), essential for liturgical prayer and a number of other rites and obligations; some astrolabes came with a book of directions for the *qibla* from various locations. They were also essential in calculating the times of the five daily prayers that vary according to latitude. Because most astrolabes were portable, one of their most popular functions was as a personal timepiece that provided the user with the means of telling time by day or night, as long as the sun or some recognisable star marked on the instrument was visible in the sky. Astrolabes were also used for surveying, such as determining the height of mountains and towers or the depths of wells.

Here follows a much-abridged and rudimentary description of the instrument and some of its functions. Most astrolabes were made of metal, especially brass, that could be engraved. An astrolabe is typically made up of four main pieces.

First is the *mater* (‘mother’) or baseplate, a hollow disk that is deep enough to hold one or more flat latitudinal plates (‘climates’, or ‘tympans’). The rim of the mater is typically graduated into hours of time, degrees of arc or both.

Second are the *plates* (‘climates’, or ‘tympans’), each of which is made for a different latitude. Each plate has engraved on it a grid marking the zenith, the horizon and all the altitudes in between. The circles of constant altitude are called *almucantars*.

Third is the *rete* (‘net’, or ‘spider’), the weblike, fretted top plate that shows the fixed stars in the ecliptic (the zodiacal constellations and certain other naked-eye stars in the part of the sky across which the sun travels). The rete is free to rotate. Representing the sky, the rete thus has the function of a star chart, and the turning of the rete represents the daily rotation of the celestial sphere. The centre of the astrolabe is marked by a hole where the rete is anchored and around which it turns; this centre represents the celestial north pole around which the stars (appear to) turn. When the rete is rotated, the stars and the ecliptic move over the projection of the coordinates on the ‘climate’ or ‘tympan’ below. A complete rotation represents the passage of a day.

Fourth is the *alidade* (‘rule’, pointer or sighting arm), with pinhole sights at each end used for making observations and reading off scales. The alidade is attached to the back face. Engravings on

the back of the mater will often give curves for time conversions from equal (or clock) hours to unequal (or temporal) hours, a calendar for converting the day of the month to the sun's position on the ecliptic, trigonometric scales and a graduation of 360° around the back edge. When the astrolabe is held vertically, the alidade can be rotated to sight a star along its length; the star's altitude in degrees can then be read ('held', 'caught', 'snatched') from the graduated edge of the astrolabe (hence the instrument's name).

A popular function of the astrolabe was to tell time. First, the altitude of the sun or of a star was found by employing the astrolabe as an instrument of observation. The marking of the sun or the star had to be found on the rete, and then the rete was revolved until that marking point coincided with the almucantar for the appropriate altitude. The sun's approximate position on the ecliptic for any time of the year could be found from the calendar scale on the back of the instrument. Once the rete was in the correct position, the observer could find his local time according to any one of several conventions. If the instrument's circumference, for example, was marked in degrees, 15° corresponded to an hour, noon was when the sun was toward the top of the instrument, midnight when toward the bottom, 6:00 a.m. when it was to the left and 6:00 p.m. when to the right.

Of the many websites that today describe the construction, functions and history of astrolabes, a very fine example is James E. Morrison's website at http://www.astrolabes.org/astrolab.htm; further links and references are at http://www.astrolabes.org/links.htm.

The Sundial. The sundial is perhaps the oldest of all scientific instruments. Sundials were in use in Mesopotamia and Egypt in the second millennium BCE. Made of many different materials, they come in all shapes and sizes, from the stationary and monumental to the pocket-size and portable. To use a sundial is simple; to understand the theory behind it, or design and manufacture sundials that reliably 'find' (not 'keep') local time, requires both observational data and mathematical calculations, and this is extremely complicated. (For this reason, most Arabic-Islamic scientists, al-Biruni among them, wrote at least one monograph on the theory and manufacture of the sundial.)

The sun shines on the dial, and a protruding 'time stick' or 'gnomon' ('the one who knows') casts its shadow on the dial plane marked with hour lines that indicate the time. (On 'time sticks', see Chapter 7.) To our modern heliocentric understanding, the mechanism depends on the Earth's rotation around the sun, but it works equally well in a geocentrically-conceived universe where the sun is fathomed as revolving around a stationary earth. The main thing is that each sundial must be designed for a specific latitude north or south of the equator; the design must also consider other factors, such as the daily changes in the sun's high point in the sky over the course of the year. (In heliocentric terms, the three main coordinates that go into making a dial are the plane of the polar axis, the plane of the equator and the plane formed by the horizon of the local latitude.)

In an article on sundials published in the January 2007 issue of *Smithsonian*, Dava Sobel, author of *Longitude*, reports on a new-age variation on the sundial that has recently been developed by the horologist and 'dialist' William Andrewes in Concord, Massachusetts, who uses electronic cartography for his designs. Each of his longitude dials is custom built for one specific location; an electronic cartography program, Geocart, provides a computer-generated map that is then laser-etched on the dial face where the meridians of longitude, projected as straight lines, double as the hour lines of the sundial for this location. To own such an instrument means never being able to use it anywhere else.

Paper

The most common writing surfaces used for recording Arabic texts during the pre-Islamic and early Islamic periods were papyrus, parchment and leather. Recorded texts were mostly religious, legal, historical and administrative. The literature also reports the use of pottery shards, bones, palm stalks, wooden slabs, architectural markers and the like as writing surfaces at the very beginning of Arabic-Islamic literacy. Even though Arabic culture was largely oral, the text of the Holy Qur'an was recorded in writing at an early age, followed probably somewhat later by written samples of the Hadith (traditions from or about the Prophet). The earliest Qur'an manuscripts were copied in brown, tannin-based ink onto parchment: the skins of goat or calf, donkey or gazelle, but most commonly sheep that had been cured, cleaned and sanded, stretched and dried and sometimes even dyed. Calligraphers penned the Qur'anic text freehand in the early, angular Kufic script on the individual folios that were then bound together in leather. Parchment was expensive and unwieldy. Papyrus was not cheap either, sometimes difficult to obtain and also brittle and difficult to store, especially in the wetter

climates. It was therefore a momentous economic and cultural leap forward when the Arabic-Islamic world acquired the technology to produce paper from pulp made of linen rags (sometimes mixed with bark).

Paper had been invented in China shortly before or after the beginning of the Common Era, where it was valued as an elite product reserved for the Chinese literary class. The paper industry was introduced to the Islamic world in Samarkand (Samarqand, now Uzbekistan) by Chinese prisoners of war in 751 CE; it is said that the Arab commander Ziyad ibn Salih had captured some Chinese paper makers at the battle of Talas who divulged the secret of paper making to their captors. Forty-some years later, Baghdad had its first paper mill, the Abbasid state adopted paper for all official business conducted by its bureaucrats, paper became part of the 'intelligence service' of the carrier-pigeon messaging system, and by the mid-tenth century almost everyone with any education used paper for all activities involving the written word. Available by mass production, the new technology generated an unprecedented public literacy. In Baghdad the caliphs Harun al-Rashid and al-Ma'mun created the first major public libraries in their realm since antiquity. Private libraries, including those maintained by professional book dealers, followed suit. By the thirteenth century, Baghdad had 36 public libraries and 100 book sellers. Ink was now carbon based and black, and the writing was harder to forge, because – unlike papyrus – ink markings on paper were not erasable. By the middle of the tenth century CE, paper had become whiter and thinner, and even the religious scholars began to use it for copying the sacred texts of the Qur'an and Hadith. North Africa and Spain at first resisted, but by the eleventh century, Spain's paper mills produced not only for local consumption but for export throughout the Mediterranean basin, and by the end of the twelfth century Fez in Morocco had 472 paper mills.

Traditional Islamic culture was text based. With the introduction of paper, it became a flourishing culture of the book. Paper was cheaper and easier to produce than parchment or even papyrus, black carbon-based ink was cheaper and easier to prepare than brown tannin-based ink, and the new (post-Kufic) cursive Arabic scripts were faster and easier to write and read. The new writing surface revolutionized literary and scientific production, its funding by wealthy patrons and accessibility by society at large. Paper played a role in the new industry of mapmaking, both terrestrial and celestial (maps drawn on cloth having been especially expensive and hard to come by). Last, but not least, paper had an even more profound impact on commerce than did the 'new (Indian) numbers' because, being easier to get and harder to forge, paper was the preferred material to record business transactions, administrative and tax data, wills, inventories, accounts and the like.

Manuscripts written on paper were relatively affordable, movable, and hence ubiquitous, so that scholars not only shared the same canon of classical texts but also kept abreast of each other's written work. Al-Biruni copiously quoted his sources from among the 'classical canon' of pre-Islamic as well as later Arabic-Islamic science; prominently quoted, for example, are the mathematicians and astronomers Muhammad al-Khwarizmi (d. *c*. 850), al-Farghani (d. *c*. 861), Ahmad ibn Abdallah al-Baghdadi known as Habash al-Hasib (d. *c*. 860), al-Battani (d. 929), Abu Ja'far al-Khazin (d. 971) and Abu al-Husayn al-Sufi (d. 986), all pertaining to the eastern part of the Islamic world and all of whom had preceded al-Biruni in checking the parameters of Ptolemy's *Almagest*. Much of al-Biruni's knowledge of the works of his own contemporaries likewise derived from his familiarity with their writings that were made public in the form of manuscripts written on paper. This holds true even for his connections with the scholars with whom he personally collaborated during the various stages in his career, such as Abu Nasr ibn Iraq in Kath, al-Khujandi in Rayy, Abu al-Khayr Khummar, Ibn Sina and Abu Sahl al-Masihi in Gurganj, and later a number of other colleagues both at the court in Ghazna and in India. Important academic linkages, whether based on personal acquaintanceship or not, were also often maintained by way of the mail, such as al-Biruni's collaboration with the astronomer Abu al-Wafa' al-Buzjani (d. 998) to find the difference in longitude of their respective locations (al-Biruni's in Kath, al-Buzjani's in Baghdad) by way of coordinated mutual timing of the lunar eclipse of 28 May 997. (The difference in local times between the two sightings of that lunar eclipse was one hour; this meant that the longitudes of the two places of observation were 15° apart, or 1/24th of the earth's circumference.)

There is a good case to be made that the introduction of paper into the Islamic world in the eighth century equalled in magnitude the cultural impact of printing and printing presses on sixteenth-century Europe. Historically, this medieval paper-industry 'revolution' also far surpassed the initial effects of printing in the modern Islamic world itself, where the manuscript culture had produced more titles in more copies than Western books had been circulating in preprint Europe. With the

exception of presses run by and for religious minorities, printing came to the Islamic world almost a full millennium after the introduction of paper making and three or four centuries after its invention in Germany. Perhaps, as many historians maintain, there existed some sort of public suspicion toward printing as a potentially dangerous, Western-grown technology, whence printing was not officially endorsed; the Ottomans, for example, did not officially support a printing press until the eighteenth century, some three centuries after Gutenberg's first invention of the technology. For cultural and religious, social and economic reasons, the 'conservative' elites of the population are said to have objected to this 'alien' technology, while the 'innovators' argued in favour of the merits of printing. In 1726 CE, Sultan Ahmed III gave permission to install the first printing press for Turkish, Persian and Arabic to publish scientific, historical, geographical, military and linguistic texts; books of religious Islamic content were excluded from the enterprise. Even so, the press was shut down in 1756 until Sultan Abdul Hamid I restored it in 1784.

While our academic literature on these facts has largely focused on ideological considerations (indigenous fear of a modern, foreign-invented technology), some revisionist historians like Muzaffar Iqbal and others have suggested that the reasons for opposing or delaying machine printing and mass publication in the Middle East and beyond may have actually derived from the very history of a successful manuscript tradition and its century-old 'culture of the book'. Government support of the manuscript culture with its workshops of scribes and copyists, calligraphers, book binders, book designers and the like meant employment for large sectors of the population and thus stood for sound economic and social planning. At least in part it was considerations such as these that stood in the way of any official or popular enthusiasm for printed mass publications.

With the nineteenth century, printing had, of course, arrived in the Islamic world; mass production of newspapers and pamphlets and books occasioned a revolution of access for an ever-larger literate readership and changed the whole tenor of cultural production and consumption. We are now witnessing a similar threshold that began with the introduction of the new electronic media.

CHAPTER 5

THE LIFE AND WORKS OF AL-BIRUNI

The Biography of Abu al-Rayhan al-Biruni and What it Tells Us about the Coherence of Medieval Islamic Civilization and the Difficulties Encountered when its Internal Politics Collide

Abu al-Rayhan Muhammad ibn Ahmad al-Biruni was born around 973 CE of a Khwarizmian-Iranian family on the outskirts of Kath, capital city of Khwarizm (modern Khorazm), located on the east bank of the Amu Darya river (ancient Oxus, medieval Jayhan), now in the Republic of Uzbekistan. Very little is known of his upbringing, except that he carried out his earliest scientific projects under the patronage of the ruling house of Kath, the Banu Iraq (or Afrighid Khwarizmshahs). His many works on mathematics and astronomy, calendars, cosmology and more were written in Arabic, leading his later biographers to assume that he first learned Arabic by the traditional methods of the *kuttab* (Qur'an school). He explained his choice of Arabic as his preferred professional language because it was the language of the Qur'an and of the Islamic realm as a whole; more specifically, Arabic had become the repository of the sciences from all parts of the world and thus provided the established idioms and terminology for any scientific enterprise. As he declared in his *Kitab al-Saydana*, Persian was ‘not a language of science’ but mainly suited for ‘historical epics and night conversations’. Worse yet would be trying to write science in his native Khwarizmian-Iranian language, since that would be ‘like harnessing a giraffe’.

The first scientist known to have played a key role in al-Biruni's educational development was the mathematician and astronomer Abu Nasr ibn Iraq (d. 1036), himself a student of the Iraqi mathematician and astronomer al-Buzjani (d. 998); al-Biruni considered these scientists as his teachers, especially in the area of trigonometry and its application to astronomy. But Abu Nasr Mansur ibn Iraq was also a prince of the Banu Iraq dynasty at Kath and al-Biruni's first patron. Still in his teens, al-Biruni thus gained access to the royal library and other educational facilities, and he began to design instruments to determine their city's latitude and other geographical coordinates.

After his early, formative years in Kath, the violent end of the Afrighid dynasty (995 CE) forced al-Biruni to relocate and look for employment elsewhere. Similar crises were to happen frequently during the early part of his life, as the volatile political situation in eastern Iran and Central Asia forced him to move between the courts and patronage of competing dynasties in the region, such as the Samanids, Buyids, Ziyarids and various Khwarizmshahs. First he went to Buyid-controlled Rayy in Iran, where he unsuccessfully tried to work for a while without support from a patron. Fakhr al-Dawla (who ruled in Rayy from 976 to 997) had founded an observatory on a mountaintop above Rayy in the year 994, just prior to al-Biruni's arrival in the city (995). This observatory was a very large structure (a sort of camera obscura?) with an opening at the top admitting sunlight; the light then transected a wall mural of lines and calculations that functioned as a mural sextant (60° meridian arc) of about 20 meters radius, built to the specifications of the court astronomer al-Khujandi (940–1000) so he could measure the altitudes of celestial bodies to determine geographical coordinates as well as observe series of meridian transits of the sun. He used these latter observations, first made on 16 and 17 June 994 for the summer solstice and 14 and 17 December 994 for the winter solstice, to calculate the obliquity of the solar ecliptic, proving that it is not constant but declines continuously with the course of time. Al-Biruni, who worked and studied with al-Khujandi in Rayy and thus appears to have had access to the research site, stipulated that al-Khujandi's calculations, including of the latitude of Rayy, were faulty, since the sextant had settled into the ground under its heavy weight, which threw off its measurements. Al-Biruni's allegation was almost certainly correct, but he still could not get a

position at Fakhr al-Dawla's court.

In Rayy, al-Biruni also appears to have established contact with the astronomer Abu al-Wafa' al-Buzjani of Baghdad, teacher of his erstwhile teacher Abu Nasr Mansur ibn Iraq, which later led to their separate but coordinated observations of the May 997 lunar eclipse time differences for conversion into a meridian determination; as al-Biruni explained it in his book *Coordinates* (1025), the algebraic difference between two observed times is the longitudinal difference between the two localities, the place of the earlier occurrence being the more Eastern.

Unable to find a patron for his work in Rayy, al-Biruni appears to have suffered poverty and encountered contempt even from other scientists, which prompted him to write a sarcastic poem (recorded in *The Chronology*, 1000 CE) that money, not manhood, is the source of a man's worth:

> A wise man of by-gone times has said: 'the importance of a man lies in his two smallest things'. I on my part also speak like a wise man, saying: 'the importance of a man lies only in his two *dirhams*'. If he has not his two *dirhams* with him, his bride does not care for him. In consequence of his poverty he is despised, so that people's cats piss at him.

Al-Biruni may now have gone back to Kath; later he went to Bukhara to work for the Samanid king Mansur ibn Nuh, upon whose death (in 999) he was recruited to join the court of the learned ruler of Tabaristan and Jurjan (located south east of the Caspian Sea in Iran), Shams al-Ma'ali ibn Qabus ibn Vushmgir (Washmgir) (r. 978–1012). Here al-Biruni, then 27, wrote his masterpiece on cross-cultural calendric time management, entitled *The Chronology of Ancient Nations* (*Al-athar al-baqiya 'an al-Qurun al-khaliya*) (presented in Chapter 6), which he dedicated to the ruler.

But around 1008, he opted to move to Khwarizm's new capital, Gurganj (Jurjaniyya, located west of the lowest reaches of the Amu Darya river, now in the Republic of Turkmenistan). There his work was supported by the Ma'munid dynasty of Khwarizmshahs: al-Hasan Ali ibn Ma'mun (who ruled from 997 to 1009 and whose father, Abu Ali Ma'mun, had annexed Kath and killed its ruler in 995) and then Abul-Abbas Ma'mun ibn Ma'mun (ruled 1009–1017). Here al-Biruni was now a member of a select group of famous specialists: Abu al-Khayr Khummar (d. 1049) worked in medicine, Ibn Sina (d. 1037) and his teacher Abu Sahl Masihi (d. 1011) were the specialists for Greek philosophy and science, al-Biruni's former mentor Abu Nasr Mansur ibn Iraq was the resident mathematics expert, and al-Biruni was put in charge of astronomy. He requested that a large observatory be erected in Gurganj where he could observe solar median transits and other phenomena. This was a 'think tank' of the first order as these elite scholars worked together closely, collaborated on projects and competed quite fiercely. The academy fell apart after the death of al-Hasan Ali ibn Ma'mun (1009), when the weakness of his successor, Abul-Abbas Ma'mun ibn Ma'mun, set the stage for the area's conquest by the Ghaznawids, a Turkish dynasty named after their base, Ghazna (now Ghazni), in east-central Afghanistan.

Ghazna's Sultan Mahmud, son of a Turkish military slave and the second and greatest of the line, was two years older than al-Biruni. By 1020 CE, he had carved out a realm that extended 1,000 miles north and south and twice as far east and west. The language of administration, diplomacy, poetry and other fine literature at the court in Ghazna was Persian, while the language of the army and military affairs was Turkish. (Starting in 1014, official state correspondence was written in Arabic.) Much of the scholarship, including most of al-Biruni's own, was written in Arabic. Ghazna must have been a quite splendid capital for this young dynasty.

Al-Biruni was in Gurganj when Sultan Mahmud conquered the city in 1017 and killed or deported the local leadership. Ibn Sina and Abu Sahl Masihi had left Gurganj in or around 1011 and thus avoided deportation to Ghazna, while Sultan Mahmud took several thousand prisoners as well as Abu Nasr Mansur ibn Iraq, Ibn al-Khayr Khummar and al-Biruni with him to Ghazna in 1017. It was a time-honoured custom of conquerors in the Islamic world to kidnap scientists of a vanquished nation, especially if they worked in the applied sciences and had engineering skills. Indeed, conquerors in all ages including our own have claimed this privilege, even though it is sometimes difficult to ascertain just how willingly the scientists themselves have gone along or even welcomed such dislocations. In al-Biruni's case, the move to Ghazna appears to have been entirely involuntary. As the Chinese proverb ominously puts it, al-Biruni lived 'in interesting times'. His fate may remind one of the cynical psychopathic character Harry Lime (played by Orson Welles) in the film *The Third Man* who opines that war is good because peace goes hand-in-hand with cultural stagnation: 'Switzerland,' he says, 'look at Switzerland… Hundreds of years of peace… and what have they produced? The cuckoo

clock.' (This now famous line was written into the script by Welles himself and does not appear in the text of Graham Greene's novella *The Third Man* on which the movie was based.) Surely, it does not take war and political turmoil to produce high culture. But when they coincide, and culture prevails, the clash presents a lesson about human endurance and creativity. Al-Biruni survived multiple flights and dislocations enforced upon him by the political turmoil of his time and place, most drastic among them his removal from his home base in Khwarizm to Afghanistan by an autocratic empire builder of great military prowess. Yet al-Biruni's scientific and literary output came to more than 140 titles and perhaps as many as 160 or 180, some very short but others of multivolume length. A good five-sixths are said to have disappeared without hope of recovery.

It appears that the relationship between al-Biruni and Sultan Mahmud was never very good. Al-Biruni never dedicated a major work to this irascible and imperious sultan, as he would to his successor. It must be said, however, that Sultan Mahmud's historical reputation as a mere robber of foreign spoils and bloodthirsty tyrant both at home and abroad has recently been questioned by some revisionist historians. They have also contested the story that the sultan mistreated the great Persian poet Firdawsi (d. 1030), author of the royal Iranian epic *Shahname*, first by withholding financial reward and then by threatening to kill him in a most violent manner after Firdawsi had composed a biting satire maligning the sultan, which threat is said to have driven Firdawsi from the Ghazna court into hiding for the rest of his life. (So it is said that if indeed Mahmud treated Firdawsi shabbily, the blame should lie with the jealous intrigues of the court poet Unsuri against Firdawsi.) Sultan Mahmud did, indeed, despoil and destroy many Hindu temples; the 17 military campaigns that he organized and led against Indian targets were legitimized as attacks on India's idol-worshipping culture, but they also served to bring in considerable wealth. Nevertheless, it is said that in his dealings with his own Hindu subjects, he could be tolerant and even promoted some to higher positions at his court.

In the literature Mahmud appears as self-willed, stubborn and impatient in the face of contradiction. His fame rests on his military prowess that combined personal courage and fighting skills with superb skills in battlefield strategy and planning. History reports that Sultan Mahmud was highly regarded, to the point of veneration, by the soldiers who were in his employ. Historical or not, a particular favourite of Mahmud's is said to have been a Turkoman Mamluk (military slave) by the name of Ayaz whose fervent devotion to the sultan became the matter of myths. Poets and storytellers fashioned the relationship between sultan and soldier into the stuff of romance. Two hundred years later, the great Sufi poet from Balkh, Afghanistan, Jalal al-Din Rumi (d. 1273), then writing in the Seljuk capital of Konya, employed the figures of Sultan Mahmud and his slave soldier Ayaz to elaborate on the themes of 'lordship' and 'servitude'. In this Sufi rendition, the virtue of total devotion – perhaps nowhere more pronounced than among military men – comes to stand for 'the lover's' (the human's) desire to serve none other than 'the Beloved' (God). Similar readings are found in the romantic–spiritual epics of the Persian Nizami (d. 1202) and the poetry and epics of the Persian Sufi writer Attar (d. 1220).

Sultan Mahmud of Ghazna was rigorously committed to the practise and protection of a strictly orthodox Sunni Islam. Like some other military rulers wishing to emphasize their regime's legality, he requested and received an official document from the Abbasid caliph in Baghdad that sanctioned his rule 'as the caliph's delegate'. He is said to have controlled his subjects' beliefs to the point where he decreed military surveillance followed by punishment of individuals accused of moral delinquency or real or suspected heresy; these included persecution not only of Isma'ilis (extremist Shi'ites) but also of Sunni scholastic theologians accused of harbouring Mu'tazilite ('overly rationalist') tendencies. In his writings, al-Biruni himself frequently voices a negative opinion of Mu'tazili scholastics. Perhaps he was put off by their hairsplitting dialectic over issues that he regarded as vacuous; given Sultan Mahmud's policies, though, al-Biruni's position may also have had a more practical, political cast.

Information on the educational facilities in Mahmud's Ghazna is scant. The sultan is said to have been an ambitious builder of spectacular library holdings in his capital with books confiscated elsewhere during military campaigns, such as 'the expurgated parts' of the famous library at Rayy that he conquered in 1029. We read that he built a university at Ghazna that had a vast collection of valuable books on all branches of literature. When he had conquered a town, all rare volumes found in the library were transported to Ghazna. He founded a splendid mosque in 1018 and attached to it a library with works of rare value collected from all parts of the empire. His brother Nasr (commander of his troops in Khorasan and also his governor of Sistan) is said to have founded the first madrassa in Ghazna and so forth. What is certain, however, is that Sultan Mahmud's court provided al-Biruni with an observatory and an array of sophisticated observational instruments, some of them of al-Biruni's

own invention, where he conducted such astronomical projects as the determination of the latitude of Ghazna and the calculation of the correct determinants of its local *qibla* (direction toward Mecca for the five daily prayers and other rituals).

Aside from Abu Nasr Mansur ibn Iraq and Abu al-Khayr Khummar, who were deported to Ghazna together with al-Biruni, we have even less information on the number, identities and specializations of scientists at the court in Ghazna and whether they fulfilled a 'think-tank' function. The sultan is said to have been a poet and legal author of some repute; he took part in the religious and literary discussions of the scholars at his court and was a renowned patron of some of the poets among them: Unsuri, Farrukhi, Asjadi and Ghada'iri. Yet even if al-Biruni did perhaps perform his work at the Ghazna court without the support and collaboration of a large group of fellow scientists, there were other opportunities for potential 'think-tank' input from travellers as well as members of the administration, such as data provided by foreign diplomatic delegations of Volga Bulghars, Chinese and Uighur Turks on the climate and geography of their remote home areas or the advice of the prominent Ghazna administrator Abu Sahl Abd al-Mun'im ibn Ali ibn Nuh al-Tiflisi (whom al-Biruni calls 'the master') that he should undertake a study of India. Al-Biruni's involuntary residence at Sultan Mahmud's court coincided with the height of Ghaznawid expansion ever farther into the Indian subcontinent, so this captive scientist was given the opportunity, or more likely the order, to travel and reside in various parts of the Punjab and areas at the borders of Kashmir. Several of the sultan's courtiers had accompanied Mahmud on his campaigns, and their news may first have stirred al-Biruni's interest in Indian culture and society, religion, literature, mathematics (arithmetic) and scientific theory, which prompted him to learn Sanskrit while still in Ghazna. Between 1020 and 1029 he himself was then permitted to travel several times to India, where he met and collaborated with Hindu scholars; later he remained in contact with some of them by way of correspondence. The result was al-Biruni's anthropological and scientific study *Investigating India* (1030).

When Sultan Mahmud died in 1030, al-Biruni's prestige at the court in Ghazna rose considerably under the two successors to the throne, first the son Mas'ud (d. 1041) and thereafter the grandson Mawdud (d. 1048). Having omitted to dedicate any of his works to Sultan Mahmud, the father (to whom he could at least have dedicated *Investigating India* posthumously), al-Biruni dedicated his next astronomical magnum opus, *The Canon Mas'udicus* (*Al-qanun al-Mas'udi*) (1031), to Sultan Mas'ud, with all the verbal flourishes and expressions of fulsome praise that were customary among the scholarly elite in thanking their royal patrons.

Al-Biruni died, probably in Ghazna, in or around the year 1050 CE. He was then 80 or more lunar years old. Did he ever marry and have children, in either Khwarizm or Ghazna or both? The copious data available to us on his scientific projects contain enough information to re-create his scholarly biography at least in outline form. The private side of al-Biruni's life remains more obscure. There are passages here and there in some of his works that sound a more personal note. There is no doubt that he was uncommonly ecumenical in his interests, a realist, endowed with an independent mind and the courage to state his convictions. He was also uncommonly modest in stating his ignorance on specific problems when he could not come up with an answer that he deemed acceptable by his own standards. He maintained cordial relationships with colleagues, especially his former teachers and students; among the works published under al-Biruni's name, for example, a number of tracts were written under his direction by Abu Nasr Mansur ibn Ali ibn Iraq, by Ibn Sina's teacher Abu Sahl Masihi who may also have taught al-Biruni, and by Abu Ali Hasan ibn Ali al-Jili. It is said that al-Biruni spoke of his own writings as 'his children' and of the writings supplied by others as 'his adoptive children'. He appears to have been a scientist's scientist, so fascinated by his projects and so dedicated to solving the problems they posed that he perceived his political and financial dependency on his patrons as a major handicap. In the book on India, he lamented his lack of freedom in conducting his researches:

> What scholar, however, has the same favourable opportunities of studying this subject as I have? That would be only the case with one to whom the grace of God accords, as it did not accord to me, a perfectly free disposal of his own doings and goings; for it has never fallen to my lot in my own doings and goings to be perfectly independent, nor to be invested with sufficient power to dispose and to order as I thought best. However, I thank God for that which He has bestowed upon me, and which must be considered as sufficient for the purpose.

But he also (and perhaps a shade more bitterly) lamented the lack of princely patronage that, he maintained, is the motor behind the rise and flourishing of scientific discoveries. On the protection of kings, he said:

> For they alone could free the minds of scholars from the daily anxieties for the necessities of life, and stimulate their energies to earn more fame and favour, the yearning for which is the pith and marrow of human nature. The present times, however, are not of this kind. They are the very opposite, and therefore it is quite impossible that a new science or any new kind of research should arise in our days. What we have of sciences is nothing but the scanty remains of bygone better times.

Of the clashing priorities of scientists and the wealthy, he said: ‘The scholars are well aware of the use of money, but the rich are ignorant of the nobility of science.’

It is probably in this context that we have to understand al-Biruni's grateful praise for Sultan Mas'ud in the preface to *The Canon*, since it was this sultan who at long last appears to have endowed al-Biruni with a stipend that enabled him to devote himself entirely and freely to his scientific work. Two centuries later, the Syrian geographer al-Yaqut (d. 1229) reported that Sultan Mas'ud offered al-Biruni an elephant's load of silver pieces as reward for *The Canon*, but that al-Biruni refused the gift. We now know that ‘an elephant's load of silver’ was an established metaphor for a very large reward. Yet even if – on some level, factually or metaphorically – this story should be true, al-Biruni must have been pretty certain that the sultan's regular support payments would securely maintain him in all his research and thus were the better deal.

What happened to Ghazna? The capital was reduced to ashes in 1149 by the rulers of Ghur, in 1221 by Genghis Khan and in 1326 by the Mongols of Persia. After these onslaughts, only two polygonal towers remained standing, which Ibn Battuta saw when he travelled through Ghazna in the summer of 1332. They say that the ruins of the old city are about 3 miles away from the new town of Ghazni. In his 1937 travelogue, *The Road to Oxiana*, the British travel writer Robert Byron described those two polygonal towers of old Ghazna as octagonal star-shaped stumps, each 70 feet high, built as commemorative towers rather than religious minarets, ‘since the ground gives no evidence that there was ever a mosque in the neighbourhood’. The smaller tower bore the name of Sultan Mahmud, the larger that of his later descendant, his great-grandson Mas'ud III, son of Ibrahim (d. 1115). Byron also describes the white marble tomb of Sultan Mahmud, located in the village of Rozah, a kilometre away, where it lay beneath a spacious dome, approached through cloisters in a rose garden and where ‘three old men were chanting from large Korans’. Byron's description of the calligraphic carvings on Sultan Mahmud's tombstone celebrates their Kufic lettering as a rousing form of visual oratory.

At present, they say, the city of Ghazni and its environs are as devastated a site as are most of the urban centres in war-torn Afghanistan.

A Brief and Selective Introduction to al-Biruni's Work

Al-Biruni had full command of the theories and data of Greek and Arabic astronomy, which he combined with a rare knowledge of Indian astronomical traditions. Within the sciences, he was attracted to areas then most susceptible to mathematical analysis. He did serious work in mineralogy, including gemology (the study of precious stones), medical and pharmacological experimentation, geology, palaeontology, geography, physics, history, (a bit of) philosophy and philology; mostly, however, he wrote on astronomy and applied mathematics. Even though he wrote several books about it, most of his biographers say that his view of the value of astrology was ambiguous. He conducted some spirited exchanges of letters (position papers) with the philosopher Ibn Sina in which he argued for the inductive approach in scientific research and against Ibn Sina's Aristotelian method of deductive reasoning. To paraphrase E. S. Kennedy's observations: al-Biruni was not ignorant of philosophy and the speculative disciplines, but he preferred to study observable phenomena as they related to nature and to humankind. Hence, the topic of time, scientifically determined as well as culturally defined, is a recurring theme in many of al-Biruni's writings.

Al-Biruni worked primarily in spherical astronomy, the calculation of planetary orbits and their applications in the composition of astronomical tables and the theory of instruments. In his monographs, he usually began with a critical overview of older theories and mathematical methods,

thereafter either opting for one from among them or proposing his own alternative theory. A famous manual of his on 'astrology', entitled *The Book of Instruction on the Elements of Astrology* (*Kitab al-tafhim li-awa'il sina'at al-tanjim*), written in or around 1029 in both Arabic and Persian, is in fact a handbook on geometry, arithmetic, geography, cosmology and astronomy, with just an introductory section or two on astrology. Al-Biruni is said to have written this book in Arabic and then rewritten it in Persian for a (now mysterious) female reader or disciple or patron named Rayhana who did not know Arabic. His astronomical magnum opus, however, is his 1031 *Canon Mas'udicus*, so titled in honour of his next-to-last patron, Sultan Mas'ud (r. 1030–41), son of Sultan Mahmud of Ghazna; this work is a great synthesis of Greek, Indian and Arabic astronomy that in its scope and brilliance has been compared to the synthesis put forth by Ptolemy in the *Almagest*. *The Canon* also contains information on the history of Arabic astronomy and its agents up to the early eleventh century.

The mathematization of the sciences had provided al-Biruni with new tools to study specialized topics within astronomy, such as the mathematical and chronological aspects of shadows; the theory, construction and use of sundials, astrolabes and sextants; the calculation of coordinates of geographical locations; and many more. His book on geodesy/mathematical geography, *The Determination of the Coordinates of Positions for the Correction of Distances between Cities* (*Tahdid nihayat al-amakin li-tashih masafat al-masakin*, translated by Jamil Ali, commentary by E. S. Kennedy), completed in 1025, belongs in this category of research. So does his book *The Exhaustive Treatise on Shadows* (*Ifrad al-maqal fi amr al-zilal*, translation and commentary by E. S. Kennedy, 2 vols), written in or around 1021, in which al-Biruni addresses problems of local time, local latitude and the ascendent on the local horizon (ascendent or ascendant: point of the ecliptic that rises above the Eastern horizon at any given moment); the book's sections on gnomons are said to show influences of Indian and Sassanian astronomy. This work encompasses the 'science of fixed moments' (*'ilm al-miqat*) to determine the hours of day and night by way of measurement and calculation, including calculating the times of the Muslim noon and afternoon prayer from angles of shadows. (On the five daily prayers and al-Biruni's book on shadows, see Chapter 7.) Al-Biruni was also a famous chronologist (a specialist in calendars and timekeeping; see Chapter 6) and a thorough investigator of several great religions and their customs whose intercultural and inter-religious, ecumenical, writings were unparalleled at the time.

The multicultural and multiethnic world of the Eastern Islamic Empire, in which al-Biruni lived and travelled, presented him with many different models of timekeeping and calendar making. His response, mainly in his early monograph *The Chronology of Ancient Nations*, written in 1000, was to record as many of these as he could find, either by doing hands-on fieldwork and tapping into local traditions or by studying written sources. Of the two methods, he appears to have preferred the study of written documents. At the same time, his expertise in mathematics and astronomy provided the solid ground from which he would judge and sometimes correct the many varying cultural manipulations of celestial phenomena.

At the behest of Sultan Mahmud, al-Biruni undertook several expeditions to India between 1020 and 1029 that included extended sojourns in the Punjab, where he was able to socialize with Brahmans to whom he presented himself as a 'student'. His brilliance as an astronomer, cultural historian and anthropologist of religion shines forth in his book *Investigating India* (abbreviated title: *Tahqiq ma lil-Hind* [*Examination/Rectification/Verification of what is Said about India*], translated by Edward C. Sachau, London, 1910) that he wrote in or around 1030. It is perhaps in this book that we can best grasp his cosmopolitanism and ecumenism. I will now briefly introduce his work on India and later give extensive examples of his chronographic work in *The Chronology of Ancient Nations*.

Al-Biruni's Book on India

Al-Biruni adhered to the medieval Arabic–Islamic, climate-dependent notion of scientific productivity, according to which only nations in the world's temperate latitudes are capable of high culture. Being neither a Muslim missionary nor convert to an Indian religion, al-Biruni was an ethnographer who studied the literary language of the Indians, one of the 'scientific nations', in order to read their books. For this text-focused approach and the elitism that went with it, Michael Cook has called him 'the world's first Orientalist'. Al-Biruni was the first and at that point the only Muslim scholar to occupy himself with Indian science since the time that Sind (in West Pakistan) had slipped away from Abbasid control in the ninth century CE. To be sure, in Muslim learned opinion the Indians had

somehow vaguely continued their ranking, alongside the Rum (Byzantines) and the Chinese, among the three or four civilized peoples outside the Islamic realm, but not much was known about them, and what was known was also often erroneous. In his introduction to *Investigating India*, al-Biruni regrets both the Muslims' lack of interest and their belittling of Indian culture and its religious expression, because they (the Muslims) 'have compiled materials never sifted by the sieve of critical examination'. Without identifying himself with Hinduism, al-Biruni wrote to celebrate India's achievements and make them accessible to scholars from other cultures, for the benefit of 'those who wish to discuss with the Hindus their religion, science and literature, on the basis of their own [the Hindus'] civilization'.

But al-Biruni's work on India was occasioned by more than this didactic purpose. His was an elitist, prized literacy that derived its energy from the conviction that Truth, 'global' and indivisible, is the property of the educated few. Franz Rosenthal has termed it al-Biruni's belief in the idea of the original oneness of all higher civilizations, the existence of an 'eternal wisdom' that higher civilizations share and that creates a strong bond between them. This formula of the elect, of course, included the civilization of Islam. Definition of the other in this divide focused neither on doctrine nor even on other, wider, cultural differences among the civilizations, but focused on the vast cadres of the illiterate on all sides, since in this scheme illiteracy is equated with ignorance and even heresy. The illiterate masses are destructive of all higher civilizations' 'eternal wisdom' and thus also destroy their essential oneness. Into his gathering of ethnographic data on Indian high culture, al-Biruni inserted comparisons with similar ideas he had encountered in his research on the Greeks and the Muslims, likewise elite cultures worthy of study, while the illiterate and superstitious masses in all three nations merited nothing but contempt. He held a low opinion of 'the Arabs' (in the meaning of pre- or early-Islamic dwellers of Arabia) because 'they are illiterate people, who can neither write nor reckon. They only rely upon numbers and eyesight. They have no other medium of research than eyesight, and are not able to determine the lunar stations without the fixed stars in them.' His cultural anthropology of India contains further strident remarks on the foolishness of Hindu polytheism, which he sometimes likened to the pagan religions of ancient Greece and then saw traces of both of their impacts in Muslim Sufism. (Obviously, al-Biruni took a dim view of Sufism in Central Asia as he knew it; politically, this may not have been a bad choice since the Ghaznawids, like other newly-converted dynasties before and after them, preferred a literalist approach to the Qur'an and Sunna.) Yet ecumenically minded though he surely was, al-Biruni was not a relativist but felt compelled to confirm the singularity and superiority of the Islamic faith and its laws, saying that 'we believe nothing they [the Hindus] believe, and vice versa', and that the difference in customs between the two cultures is such that 'if ever a custom of theirs resembles one of ours, it has certainly just the opposite meaning'. Snippets like these surely serve as satirical warnings against the danger of turning the highly abstract notion of the unity of higher civilizations into a relativist mush, but they also belie al-Biruni's patient perseverance in cross-cultural discourse.

Al-Biruni's book on India deals with Hindu cosmology, astronomy, astrology, physics, geography, Hindu religion, beliefs and practises, festivals and feast days, pilgrimages, holy rivers and cities, and Hindu eras of timekeeping. The arrangement of these topics is significant: of the 80 chapters, the first 12 deal with philosophy and religious doctrines (God, Creation, soul and matter, metempsychosis, salvation and idolatry), while the last 16 chapters deal with ritual practises (sacrifices, pilgrimage, almsgiving, dietary laws, sex, marriage and children, legal matters, funerary ceremonies, obligatory sacrifices, dietary rules, fasting and lucky and unlucky times or days). Philosophy is thus equated with doctrine, and religion with ritual and worship, and each is separated from the other by the book's bulk that deals mainly with Hindu science and its branches. The two categories, 'doctrines' and 'ritual and worship', are well-known principles of classification in Islamic religious thought and literature. In both sections, al-Biruni also adduces voluminous cross-cultural parallels from Greek and Persian, Jewish, Christian and Sufi sources that introduce the subject matter in a comparativist and reader-friendly fashion. The roughly 50 chapters in between these two thematic blocs however, are the stuff of specialists, especially on the topics of Hindu cosmology, astronomy and chronography. Here, al-Biruni does not write history but science, where the common denominator of widely varying traditions lies in the laws of mathematics and the established theories of astronomy that render them all comparable.

Al-Biruni engages in a sophisticated dialogue with the great Hindu texts by the likes of Aryabhata (late fourth and early fifth centuries), Brahmagupta (d. 668 CE) and many others that reflects his respect for Indian science. Even though he finds that Ptolemy's data are on the whole better than

those of the Indians (who also did not know the astrolabe), Indian science can be a positive challenge to the Greek, and opening Greek and Indian high culture to each other will render the latter part and parcel of an intercultural, global civilization. If, on the other hand, Indian astronomy has a feature that Greek astronomy did not, al-Biruni cites and critiques it on its own merits. For example, reporting on the different Hindu debates regarding the rotation of the earth (see Chapter 4), al-Biruni concludes that there is no difference between heliocentrism and geocentrism from a purely mathematical perspective; thus, the question of whether the earth rotates or is at rest bears no importance for a scholar in mathematical astronomy but is a physical–philosophical problem that should be investigated by the physicist.

Other aspects of the Indian canon were harder to access, let alone coordinate with known Greek, Persian or Islamic systems and traditions. For example, al-Biruni found the many ‘eras’ of the Indian calendar too huge and impractical for reckoning and their ‘centennium’ subsections of 101 years each too difficult to pin down chronologically. In order to coordinate the Hindu calendar with the Persian Yazdigird calendar familiar to most of his readers, he established correspondence between the two by selecting the year 400 of the Yazdigird as his ‘gauge year’ for comparison (since the Hindu year had begun just 12 days before the other). (On the Yazdigird calendar, see Chapter 6.) But he was unable to coordinate the many time systems in India in this fashion and apologized for the imperfection of his data, saying that the popular mode of dating in use among the Hindus, if exceeding a centennium, ‘is confused’. Instead, he often chose to focus on the religious myths that underlay much of the lore on the Indian calendar.

According to al-Biruni, the main thing wrong with Indian cosmology and astronomy is not the quality of the science but the gullibility of the scientists who cave in to pressures of popular superstition, fail to dispel popular myths and fall short of producing worthy scientific research. (This is where the Greek striving for Truth can and should be a model.) Weakness of the Indian system, in other words, lies with the astronomers who lack the courage, honesty and professional ethics to stand up to the masses and their silly notions of ‘all kinds of religious dogmas which the vulgar belief does not admit to being called into question’. The Hindu public is guided to fulfil the rules of its religion by its astronomers' books, so astronomers are well liked and highly regarded. In return, the astronomers accept without criticism the public's ‘popular notions as truth, by conforming themselves to them, however far from the truth most of them may be, and by presenting them with such spiritual stuff as they stand in need of’. Some astronomers conceal the truth from the masses. In consequence, al-Biruni compares their mathematical and astronomical literature – as far as he knows it – to ‘a mix of pearl shells and sour dates, or of pearls and dung, or of costly crystals and common pebbles. Both kinds of things are equal in their eyes, since they cannot raise themselves to the methods of a strictly scientific deduction’. Clearly, it is only the separation of pure religion and pure science, and the cultural autonomy of each, that guarantees the excellence of any theology and science, Islamic or otherwise.

It is perhaps curious that al-Biruni's *Investigating India* was dead upon arrival in the flourishing manuscript culture of his time. Part of the reason may have been the book's comparative focus on Greek, Arabic-Islamic and Hindu elite culture; perhaps another reason was al-Biruni's choice of Arabic as his ‘language of science’. The Turkish sultans from the Ghaznawids to the Moghuls patronized art, not science, and preferred Persian as their cultural medium; Arabic was the language of religious and legal scholarship, but *Investigating India*'s subject matter went beyond these disciplines. Filled with (untranslated) Sanskrit terminology, it was also a cumbersome text to read. Wassilios Klein suggests that the book appeared at the wrong time and in the wrong place, written in the wrong language. It was only with the rise of modern Indology in the nineteenth century that it came into its own.

CHAPTER 6

CALENDARS BY THE BUSHEL

Al-Biruni's Work on the Measurement of Time

In his works on astronomy and calendars, al-Biruni mainly employed plane and spherical trigonometry. Whereas the abstract models of his planetary theory are essentially based on Ptolemy, he also made use of copious additional data derived from observations, including his own. As related above, algebra and algorithms had been developed by Muslim mathematicians well before al-Biruni's time, prominent among them Abu Ja'far Muhammad ibn Musa al-Khwarizmi (d. *c*. 850), who had worked mainly in Abbasid Baghdad. Planetary and spherical trigonometry had also been developed by the Arabic scientists far beyond their Greek beginnings.

Trigonometry had made inroads into India in the form of some pre-Ptolemaic version of Greek mathematical astronomy that had differed from the later Greek system in both content and method. Its influence on Arabic-Islamic astronomy and mathematics left its mark on Caliph al-Mansur's Baghdad in the 770s, until Ptolemy's theories rose to prominence in the 830s with the foundation of Caliph al-Ma'mun's Bayt al-Hikma. In his book *The Mathematics of the Heavens and the Earth: The Early History of Trigonometry*, Glen van Brummelen states that *sine* is not only a Latin translation of the Arabic term *jayb* (a 'fold', or 'inlet', also a 'breast pocket', 'curve of a garment' or 'opening of an angle'), but the term *jayb* itself originated as a transcription of the Indian *jya* ('chord').

The full system of trigonometric functions of sine and tangent, cosine and cotangent is usually attributed to the mathematicians and astronomers al-Battani (d. 929) or al-Buzjani (d. 998), but, according to George Saliba, this honour may actually belong to Habash al-Hasib (d. *c*. 860), one of Caliph al-Ma'mun's court astronomers in Baghdad who was the first to use the tangent function to solve astronomical problems outside of gnomonics (i.e., telling time by the shadow cast). Al-Biruni knew and frequently quoted Habash al-Hasib's writings. In his own works, however, he preferred to give credit to his teacher and earliest patron, Abu Nasr Mansur. The fact that al-Biruni preferred to work by way of trigonometry rather than algebra was perhaps partially due to his self-declared discipleship of Ptolemy, meaning (in a larger sense) that even the new Arabic trigonometry had more connections with Greek methods of calculation than did the new Arabic algebra. It was only later that al-Tusi (d. 1274 CE) endeavoured to establish trigonometry as an independent field of mathematics and not an appendage of geometry or, for that matter, algebra. Modern scientists and historians of science, such as E. G. Richards, author of *Mapping Time: The Calendar and its History*, prefer algebraic methods, now readily available with computers.

Given the advanced level of theoretical and applied science in the ancient and medieval Eastern world, the degree to which this knowledge was made available to him and his genius in embracing and building upon it, it follows that al-Biruni's works on the calendric measurement of time are exemplars of hard science. By his own inclination, they are also studies in comparative religion and anthropology. In his capacity as global astronomer, al-Biruni knew full well that calendars are mental constructs. Thus, he dwelt on calendars as exemplars of distinct cultural efforts at 'time-framing' throughout history. As an astronomer and mathematician, he also took delight in correcting some of the data in the written calendars that he studied and recorded. His major contribution to all later historians, however, surely lies in the fact that he endeavoured to synchronize the many various calendric systems that he encountered in his studies. His interest in calendars informed many of his major works, such as his study on Indian culture, religion and science, *Investigating India*, presented above; the *Epitome of Star Tables* (*Ghurrat al-zijat*), an Arabic translation of a Sanskrit astronomical handbook on calendric rules; and his *chef d'oeuvre*, *The Canon Mas'udicus* (*Al-qanun al-Mas'udi*), the

most comprehensive of his astronomical works. In this book, al-Biruni put forth the general principles of his cosmology, followed by a discussion of units of time measurement, calendars and regnal and chronological tables. The work most specifically focused on calendars, however, is surely al-Biruni's first scholarly book that he completed at age 27, *The Chronology of Ancient Nations* (*Al-athar al-baqiya ‘an al-qurun al-khaliya*), which is presented in what follows. This work was translated into English by the German Orientalist Edward Sachau (who later also translated al-Biruni's *Investigating India*); it was first published in London in 1879.

Al-Biruni's Chronology of Ancient Nations

Al-Biruni was neither a missionary nor a cultural imperialist, but an ethnographer and natural scientist who studied calendars as cultural artefacts, and he did so without prejudice. This has also rendered his work an important source for the history of religions. His own Islamic calendar measured the day from sunset to sunset, the month from observed new moon to observed new moon, and the year as the span of time between the beginning of a first month and the end of the twelfth month after that. This was what the Qur'an said about time measurement, but to al-Biruni this did not mean that the Islamic calendar was the only, or even the only God-given, frame of time reference. He was aware that some people began their months not with the first sighting of a new moon but with the disappearance of the old, and yet others used an interpolated date of conjunction with the sun, when the moon is not actually visible. As he researched and calculated calendars, prayer times, the beginning and end of religious seasons, and the orientation toward sacred places and structures in many cultures, he did so in a comparative mode.

He begins this calendric study by stipulating that the most apparent and fundamental chronological unit in any calendar is the day; then he discusses the many definitions of what constitutes ‘a day’ – the period from sunset to sunset or sunrise to sunrise (horizon based), or noon to noon or midnight to midnight (meridian based) – and names the systems that employ them. Then he defines the several varieties of ‘year’ on which calendars are based – lunar, solar, lunisolar – and introduces the notion of intercalation. Among the chronographies, many of which stipulate specific events as their starting dates or are named after their creators or patrons, he discusses the eras of Creation, the Flood, Nabonassar (Nebuchadnezzar), Philip Aridaeus, ‘Alexander’, Augustus, Antoninus, Diocletian, the Hijra, Yazdigird III, the reform of Yazdigird's calendar by Caliph al-Mu'tadid, the calendar of the pre-Islamic Arabs and that of his own native Khwarizm. Next come lists of the months’ names, with variants, as used by the Persians, Soghdians, Khwarizmians, Egyptians, ‘Westerners’ (Spaniards?), Greeks, Jews, Syrians, pre-Islamic Arabs, Muslims, Indians and Turks. These are followed by chronological and regnal tables in years, sometimes with months and days, for the Jewish patriarchs and kings; the Assyrians, Babylonians and Persians; the pharaohs, Ptolemies, Caesars and Byzantine emperors; the mythical Iranian kings; and the Achaemenid, Parthian and Sassanian dynasties. A series of tables sum up the intervals between these disparate eras. Special emphasis is placed on the Jewish calendar, which is the focus of several of the book's chapters. Except for the work of the ninth-century mathematician and astronomer Abu Ja'far al-Khwarizmi, mentioned above, who is said to have written on the Jewish calendar while employed in Abbasid Baghdad, al-Biruni's is the earliest extant scientific discussion of the Jewish calendar in Islamic literature.

The remainder of al-Biruni's *Chronology* is then mainly dedicated to descriptions of the holy days and fasts and feasts of the following peoples: the Persians, Soghdians, Khwarizmians and Greeks; the Jews and Melchite Christians (Jewish Passover and Christian Lent); the Nestorian Christians; the Magians and Sabians; the pre-Islamic Arabs; and the Muslims. The concluding chapter gives tables and descriptive matter on the lunar mansions, followed by explanations of stereographic projection and other plane mappings of the celestial sphere.

The text of al-Biruni's *Chronology* is frequently spiked with anecdotal asides and personal musings and observations, such as on the rivalry between Judaism and Christianity regarding calendar issues, or the rise of charlatans and the credulity of gullible folks in all manner of religions, including his own. This makes the book a much more personal document than a listing of its mere data would suggest. Al-Biruni wrote that he preferred to intersperse his more technical texts here and there with spurious information so as not to ‘fatigue the reader’, which is why in the middle of a section on the computation of eras, for example, we come across a description of the game of chess, partly played with dice in al-Biruni's time, which he follows with a series of game strategies that appear to be based

on what we would now call probability theory.

Of the many time systems presented in his *Chronology*, al-Biruni favours some over others. He is more enthusiastic and expansive, more energetic, in providing calculations and tables and cultural lore on some of his examples than others. In part it may be the material he knows best that receives the broadest coverage (this is a possibility but one that we cannot prove or disprove because we know too little about his sources). In part, the reason may also lie in a calendar's importance in terms of its pervasiveness. We may note that he covers some religions and their calendars, such as Manichaeism, that were on the decline during his time, in abbreviated and desultory fashion. Apparently, al-Biruni had considerable knowledge of Mani (d. 276 CE) and Manichaeism, a dualistic religion that was persecuted by the Abbasid state after 780 CE, but later he wrote that he was disappointed in their literature and eventually came to regard them not as a religion but as a 'splinter movement'. Manichaeism is discussed in a chapter titled 'The Eras of the Pseudo-prophets and Their Communities Who Were Deluded by Them, the Curse of the Lord Be upon Them'. In the same chapter, al-Biruni also discusses the Sabians (whom the Qur'an mentions in Sura 2:62 as a monotheistic religion). To al-Biruni's knowledge, (pagan) Sabians were centred in Harran, Syria, who began their day at sunrise and performed their prayers by exact solar position at sunrise, high noon and sunset (see Chapter 7), but there were also remnants of Jews in Mesopotamia 'left over from the Babylonian Captivity that had added some doctrines of the Magians to their own' who had adopted the name of Sabians, and then there were some Manichaeans who had fled to Samarkand in Khorasan to escape further persecution who had also identified themselves as Sabians. In either case, al-Biruni's coverage of their religion, or religions, is extremely brief, if we can go by the evidence of the transmitted text that underlies Edward Sachau's translation. (A major lacuna in that text has – perhaps suspiciously – eliminated the book's segments on Zoroaster and Zoroastrianism from this chapter.) The pre-Islamic Arabs of the Arabian Peninsula likewise fail to arouse al-Biruni's special interest. He does discuss their lunisolar calendar, and their market and feast days, but in a perfunctory way, and appears to have an especially low opinion of the 'primitive pagan Arabian Bedouins'.

Judaism and Christianity, on the other hand, receive his primary consideration, as do the calendars of the Persians. Clearly, the monotheistic nature of these two Religions of the Book is the impetus to explore their theologies, sectarian histories and chronological systems; both communities and their writings were amply represented and available in al-Biruni's world. In the case of Iran, challenge and interest grew from al-Biruni's own native roots. Yet one wonders whether al-Biruni did not perhaps also favour the really difficult calendric systems over the smooth and simple. Of the many calendars he knew, surely the Jewish was the most complicated, and he devoted several chapters and chapter segments of his book to analyzing and explaining it. Second in line, Christianity was an amalgamation of different churches with their different calendars and different feast days, about which he was profoundly knowledgeable. Third, the pre-Islamic Iranian calendar was an example of how the Iranian state and government had truly mismanaged the time frame (intercalation policy) of their national calendar, either after the Arab invasion or more likely before; it may have been this calendric conundrum that attracted al-Biruni's special interest. According to his calculations, the Abbasid Caliph al-Mu'tadid's reform of the Persian calendar in the ninth century CE did repair some of the slippage that Iran's long negligence of their intercalation policy had wrought on the date of Nawruz, 'New Year's Day', of the Persian fiscal year; al-Mu'tadid postponed it by 60 days from early spring to 11 June, while according to al-Biruni postponement by 77 days to 28 June would have been correct (see below). By contrast, the Islamic Hijra calendar, described in Chapter 2, is not among the time systems that merit his special attention. As for any good scientist, it may have been the 'complex', the 'complicated', rather than just the 'prominent' that influenced al-Biruni's choices.

Al-Biruni's Description of the Jewish Calendar

Al-Biruni's knowledge of the Jewish religion, its scripture, calendar and ritual celebrations is an outstanding example of premodern intercultural scholarship. In an Islamic setting, it is largely unprecedented. There was little secondary research for al-Biruni to rely on, so his work is mainly based on primary sources such as the Hebrew Bible that he probably knew in the form of the Syriac Christian Old Testament called the *Peshita* (or *Peshitta*). Jewish communities abounded in the Middle East and Central and East Asia during al-Biruni's time. He also appears to have had personal contacts with Jewish individuals, one of whom he mentions as an acquaintance during his sojourn in Gurganj. Al-Biruni was aware that the Torah was originally written in Hebrew and that Jews contested the

authenticity of its later translations by Christians into Greek and Syriac. Arguing from within the Jewish self-understanding as God's chosen people with God acting in their history, al-Biruni understood the true nature of Jewish festivals: more than just occasions of communal remembrance, they were occasions of ritual reenactment. In some instances he recorded local liturgical and ritual traditions (such as the Khwarizmian-Jewish festival of Purim) that expanded upon the scripture-based canon. As pointed out by Wassilios Klein, al-Biruni was aware of the identity and numbers of the Jewish communities of his time, such as the Rabbanim, Karaim, Ananiyyim, Maghariyyim and Alfaniyyim.

Al-Biruni gives the starting date of the Jewish calendar as 3761 BCE – the Creation date of Ben Halafta, whom he does not mention by name. (On these and several issues here following, see Chapters 1 and 2.) The mathematics becomes apparent in his several comparative tables that coordinate between the Jewish calendar, the Seleucid-era 'calendar of Alexander' and the Christian calendar, the latter cited in its (Dennis the Little's) 'AD form' (whom he also does not mention by name) that was in use among the Christians in Syria and elsewhere during al-Biruni's time. By 'comparing', as he called it, for example, 'between' Christian year 993, Jewish year 4754 and Alexander's year 1305, al-Biruni was calculating from a Christian base of AD (CE) 1, a Jewish base of 3761 BC (BCE) and an Alexandrian base of 312 BC (BCE).

Al-Biruni also knew that the Christians had a different AM (*Annus Mundi*) calendar of their own that, according to his sources, placed the date of Creation 1,732 years before the Jewish date, that is, into 5493 BC (BCE) (5500 in most early Western sources). In addition, he knew of another Christian AM system that reckoned time 'from the great Deluge, in which everything perished at the time of Noah', and that occurred 1,792 years after Creation according to the Jews and 1,938 years after Creation according to the Christians. That these figures are inconsistent with the numbers in either system is due, according to al-Biruni, to 'difference of opinion, confusion [… T]he Jews derive [the dates] from their Torah and the following books, while the Christians derive [them] from their Torah.' Al-Biruni explains this difference in millenarian terms, indicating that according to his sources, the 1,732-year difference between the Jewish and the Christian AM (Creational) calendars derives from the opposing millennial expectations of the two communities.

The Christians reproach the Jews with having diminished the number of years with the view of making the appearance of Jesus fall into the fourth millennium in the middle of the seven millennia, which are, according to (both of) their view(s), the time of the duration of the world, so as not to coincide with that time at which, as the prophets after Moses had prophesied, the birth of Jesus from a pure virgin at the end of time was to take place. But quoting a different Jewish tradition – that 'the rebuilding of the Temple or the coming of the Messiah was promised to the Jews at the end of 1335 years after Alexander' (i.e., in AD/CE 1023), al-Biruni also noted the rise of millenarian movements among the Jews in his own time, the early eleventh century. Considering the historical cross-cultural effect that round, millennial numbers in one religious calendar have had on the apocalyptic date lines of another's, these Jewish messianic movements mentioned by al-Biruni were most likely linked to the first Christian millennium, even though the quoted tradition's numerical formula (calculating from the 'era of Alexander') disguised that fact.

The technique employed by the esoteric fringes of Judaism, Christianity and Islam (and many other religions) in their messianic predictions derived from counting the numerical value of words in holy texts (the Arabic term for this activity is *hisab al-jummal*, which is notation of the numerals of the Arabic alphabet, arranged according to the sequence of the Hebrew alphabet). For the scientist al-Biruni, this approach was entirely futile, since to his mind all such interpretations 'remain assertions which they cannot support, and fallacious subtleties'. No wonder, then, that al-Biruni also took a dim view of Sufism, where numerology is often practised, and that he was deeply critical of the esoteric fringes of Shi'ism, where numerology achieved doctrinal importance. Since his own lifetime in the late fourth and early fifth centuries of the Hijra calendar fell well short of his own calendar's first millennial date, al-Biruni in his largely Sunni environment was arguably less exposed to homegrown millennial expectations and esoteric calculations. In addition, his later masters, the Ghaznawids, were literalist in their Islam and therefore averse to numerology. In any case, while the millenarian theme and its effect on calendar making appear several times in al-Biruni's *Chronology*, those instances are usually related to religions other than Islam.

(In the following sections of this chapter I have consulted E. G. Richards' *Mapping Time* to help me follow al-Biruni's analysis of the intricacies of the Jewish calendar.) The Jewish calendar presented

the scientist al-Biruni with multiple cultural and astronomical challenges. One was the calendar's lunisolar nature that required intercalation. Another was the fact that one of the feast days always has to fall both on the same calendric date in the lunisolar year and also on a specific date in the lunar cycle. And a third was that certain days of the Jewish seven-day week are off-limits for the celebration of any of the holidays. Al-Biruni investigated these issues in a rigorously descriptive mode with the help of diagrams and tables, followed by an analysis of the principles underlying Jewish computational practises, which he concluded with a series of mathematical formulas to reexamine the data and provide for calendar conversions. The years and months of the Jews, he opines, 'are very intricate and obscure, and offer many difficulties for calculation'.

The Jewish religious year starts with the spring month of Nisan (the seventh month of the civil year), while Rosh Hashanah, New Year's Day of the Jewish civil year, is the first day of the month of Tishri, which falls in the autumn (and is the seventh month of the religious year). The average length of the civil year is the same as the average length of the astronomical year, but the beginning of the civil calendar (first day of Tishri) is subject to postponements. Al-Biruni relates the reasons that the Jewish calendar is lunisolar:

> The sum total of the days [in the 12 months of the year] is 354, being identical with the number of days in the lunar year. If they simply used the lunar year as it is, the sum of the days of their year and the number of their months would be identical. However, after having left Egypt for the desert Al-tih [Gebel el Tih in the Sinai], after having ceased to be the slaves of the Egyptians, having been delivered from their oppression, and altogether separated from them, the Israelites received the ordinances and the laws of God, described in the second book of the Torah. And this event took place in the night of the 15th Nisan at full moon and spring time. They were ordered to observe this day, as it is said in the second book of the Torah (Exodus XII, 17, 18): 'Ye shall observe this day as an ordinance to your generations for ever on the fourteenth of the first month.' By the first month the Lord does not mean Tishri, but Nisan; because in the same book he commands Moses and Aaron, that the month of Passover should be the first of their months, and the beginning of the year (Exodus XII, 2) [...] In consequence, they were compelled to use the solar year and lunar months; the solar year in order that the 14th Nisan should fall in the beginning of spring, when the leaves of the trees and the blossoms of the fruit trees come forth; the lunar months in order that, on the same day, the body of the moon should be lit up complete, standing in the sign of Libra.

These restrictions necessitated the intercalation of leap months into the Jewish lunar calendar to bring it in line with the solar year. Al-Biruni examines and calculates the five existent models of intercalation in the Jewish tradition, of which the 'Minor Cycle' (seven leap months in 19 years) is the most popular; 'they prefer it to others, because they attribute its invention to the Babylonians'. This attribution is most probably correct; the 7:19 cycle is often referred to as 'Metonic' because an Athenian, Meton, was thought to have invented it in or about 432 BCE, but the Babylonians appear to have done so previously. The cycle gained prominence in Judaism with the fourth-century CE calendar reform of Rabbi Hillel II (whom al-Biruni does not mention).

The Jewish calendar is made vastly more complex by the fact that certain days of the week are off-limits for the celebration of feast days, either to prevent the Sabbath being turned into a workday or that a feast day immediately preceding or following the Sabbath would create a sequence of two consecutive days on which necessary tasks, such as preparing food or burying the dead, are forbidden. These restrictions require calculations on when the first day of a lunar month containing a major Jewish festival must be postponed or, sometimes, advanced.

Here al-Biruni provides the reader with a massive array of tables and diagrams, among which the computation of Passover holds prominence. Yom Kippur (the Day of Atonement, observed on 10 Tishri) may thus not fall on a Friday or Sunday, nor Hoshanah Rabba (Festival of Willows, observed on 21 Tishri) on a Saturday. One or the other of these contingencies would arise if the first day of Tishri, Rosh Hashanah, were to fall on a Sunday, Wednesday or Friday ('the days of the Sun and his two stars, Mercury and Venus'); in this case, Rosh Hashanah is postponed or, sometimes, advanced. Likewise, Passover, by which the beginning of Nisan is regulated, shall not fall 'on the days of the inferior stars', that is, Monday, Wednesday or Friday, and must be either postponed or advanced. Al-Biruni provides a long description of the reasons for these postponements, preceded by a table that lists the forbidden days:

• for the first day of Tishri (Rosh Hashanah): Sunday, Wednesday, Friday;

• for the first day of Yom Kippur: Sunday, Tuesday, Friday;

• for the first day of Purim or Haman Sur: Monday, Wednesday, Saturday;

• for the first day of Passover: Monday, Wednesday, Friday;

• for the first day of Azereth (Feast of Congregation): Tuesday, Thursday, Saturday.

In consequence of these calendric postponements and advancements, there are three types of years in the Jewish calendar: the imperfect (deficient), the intermediate (regular) and the perfect (abundant), each of which may be either a common year (respectively, 353, 354 or 355 days long) or a leap year (383, 384 or 385 days long according to the type of year), which yields a combination of six species or types of year. Ensuring that the lengths of all years remain within defined limits can be a further reason to postpone Rosh Hashanah, but in this case it would be the Rosh Hashanah of the preceding year. Al-Biruni deals with these issues by providing a wide array of diagrams and tables.

None of these peculiarities are shared by the Islamic calendar, which has a strictly lunar year and, therefore, movable feast days. Yet al-Biruni observes that even the beginning of a lunar month is determined differently in Judaism from how Muslims determine it, since Judaism employs a theoretical moon (as does the Christian calculation of the date of Easter); each lunation is initiated by a *moled* (or *molod*), which is the moment of conjunction of the theoretical moon, computed by the mean, not the apparent motion. The interval between successive moleds is taken to be a constant 29 days, 12 hours, 793 chalakim (one hour is 1,080 chalaks, so 793 chalakim equals 44.055 minutes); al-Biruni correctly calculated that the interval between successive conjunctions of the real moon is sometimes greater than this, sometimes less. (According to Richards, in *Mapping Time*, the interval between two *moleds* may be compared to the average synodic period of 29.53,058 days, a figure already known to the Babylonians in 300 BCE. The agreement is exact to where the *moleds* will remain in step with the average moon to within a day's span for more than 16,000 years.)

Al-Biruni also relates how this Jewish *moled* practise came about. According to ‘the sect of the Rabbanites’, as he calls them, the practise was necessitated by Samaritan deception. After the Babylonian Captivity (597–538 BCE), the Jews, now back in Jerusalem, would send guards into the hills above the city to watch for the appearance of the new moon. As soon as the guards had sighted the new moon, they lit fires to produce clouds of smoke that served as a signal to those down below that a new month had started. This went on until some Samaritans deceitfully sent the signal one day early for several months in a row. So the community, now forced to rely on calculation rather than observation, began to deduce the moment of the (theoretical) conjunction of sun and moon from both of their mean motions, regardless of whether the new moon was already visible. Now the question arose whether this innovation was within the law. To prove that it was, they cited the precedent of Noah, who during the Deluge had determined the beginning of the month by calculations, when the sky above his ark was covered by dense clouds. Other ‘Rabbanites’, however, explained that the switch from observation to calculation of the new moon occurred because the scholars and priests in Jerusalem feared communal dissension in the diaspora if the faithful were to sight the new moon at many different times, depending on their location. (We might add that the Jewish practise of using a theoretical moon to calculate the beginning of a new lunar cycle is often linked to the calendar reforms undertaken by Rabbi Hillel II in the fourth century CE, but whom al-Biruni does not mention.) Since the conjunction is computed by the mean, not the apparent motion, Passover frequently falls two complete days later than the real opposition: one day in consequence of the equations and one day in consequence of postponing Passover from a forbidden to a permitted day of the week.

This brief and simplifying summary does not do justice to al-Biruni's extensive texts on the Jewish calendar that constitute several detailed chapters and segments of chapters in *The Chronology of Ancient Nations*. Comparing his text on the Jewish calendar with modern sources that can now rely on a millennium's worth of additional work on the subject as well as special computer programs to solve the calendar's many mathematical problems, the wealth and accuracy of al-Biruni's data are astounding.

Al-Biruni's Description of the Christian Calendars, Christian Feast Days and the Calculation of Easter

Al-Biruni was familiar with several Christian churches and had book knowledge of several more. Surrounded by Christian communities in Central Asia, he had ample opportunity for scripturalist study, observation and interfaith dialogue. He was fully conversant with the Christian Bible and its early interpreters, Christian doctrinal history and also later Christian practise, meaning that he was probably in active contact with some Christian scholars of his own time. Dogmatic differences between the Christian churches are based on differences in Christology (the definition of the nature of Christ), which he explains clearly and with competence.

The Melchite (Melkite) Christians had religious centres in Nishapur and Tashkent, and the east Syrian Nestorians had centres in Marw and Samarkand. Most of al-Biruni's information on the Christian calendar derives from 'the Syrian calendar celebrated by the Melchite (Royalist) Christians, that is, the Greeks, so called because the Greek king is of their persuasion. In Greece there is no other Christian sect beside them.' Greece, of course, here means Byzantium, in the rendering of the Arabic term *Rum* by the *Chronology*'s translator, Edward Sachau. Today, *Rum* means something very generally defined as 'of Western origin or provenance'. For al-Biruni, it may have still retained the original connotation of 'Rome' – Byzantium being the eastern Roman Empire – because he also uses the term when describing the destruction of the second Jewish temple in Jerusalem (71 CE) as 'the work of the *Rumi* kings, Vespasian and Titus'. The Melchites were those Christians (of Syria and Egypt and places farther East) who remained in communion with the see of Constantinople by accepting the decree on the Nature of the Incarnate Christ issued by the Council of Chalcedon in 451 CE. There were Melchite Christians in al-Biruni's native Khwarizm who depended on the patriarchate in Antioch. His rendition of the calendar of saints and feast days of the Khwarizmian Melchite community is the only text of its kind in existence. Today the term Melchite applies to the Christians of the Byzantine rite, particularly the Uniate (or Uniat) Eastern Catholic churches in communion with Rome who retain their respective languages and rites. Al-Biruni also knew about the Nestorian Christians, who constitute 'the majority of the inhabitants of Syria, Iraq, and Khurasan' and 'whose doctrine was declared a heresy at the Council of Ephesus' (431 CE), and also the Jacobites, 'who mostly live in Egypt or around it', by which he clearly means the Copts. Likewise, he had heard about Arianism (which teaches that Christ was created, not begotten) and remarks that 'their theory regarding Christ comes near that of the Muslims, whilst it is most different from that of the generality of the Christians'.

The Melchite calendar is solar and follows the Julian in the number of days per month, including the intercalation of one day every four years in the month of February. But the year begins in October, as does the Jewish civil year:

> The Christians in Syria, Iraq, and Khurasan have combined Greek and Jewish months. For they use the months of the Greeks, but have adopted the first of the Greek October as the beginning of their year, that it might be nearer to the Jewish new year.

(Unlike the 'Syrian year', the 'Greek year' commences with 1 January, so the interval between the two New Year's Days is 92 days.) The Melchite calendar is marked by a succession of holy days, many of which are sanctified by their association with Christian saints. On a saint's day his memory is celebrated, children born on that day are given his name, and they in turn have special festivities to mark their name's day. As al-Biruni reviews the major feast days, he also reviews some of the hagiography and provides explanations of both to readers unfamiliar with Christian doctrine and ritual. Clearly, he was familiar with the Gospel as well as with numerous writings by and about Christian churches and communities. In contrast, his exposition on the birth of Jesus from the Virgin Mary is extremely short; al-Biruni knew that he could tell his readers very little that was new about Jesus's birth from the Virgin because that story is part of Qur'anic dogma (see Wuaran Qur'an 19:16–35; 23:50; 66:11–12; 21:91; 3:33–7, 42–7), and many wondrous tales surrounding the nativity had long been familiar to Muslim audiences from the Hadith literature and other pious lore. What the Melchite Christian calendar adds to the Qur'anic story are the specific dates of some of the events: 15 March for the Annunciation and, 'nine months and five days later, December 25 for Jesus' birth'. The Jacobites celebrate the Annunciation on the tenth day of Jewish Nisan, which is the sixteenth day of the Syrian month of Adhar (March). By contrast, the Nestorians celebrate the Annunciation four weeks before Christmas at the beginning of Advent, that is, the last Sunday in November or first Sunday in December. According to al-Biruni, their feast of the Annunciation is on the first Sunday of December if the first of the month falls on a Friday, Saturday or Sunday, but if it falls on Monday, Tuesday, Wednesday or Thursday, it is celebrated on the last Sunday of November.

Different from his abbreviated rendition of the Annunciation and Jesus' birth is al-Biruni's entry for 6 January, feast of the Epiphany, 'that commemorates Jesus' baptism by John in the river Jordan when the Messiah was thirty years of age', because here is a Christian ritual – baptism – that requires an explanation for a Muslim readership. There is a lengthy quote from an Arabic source on the topic, but it is preceded by what appears to be an eyewitness report on a baptism, presumably al-Biruni's own account:

> Now Christians practise the same [as Jesus's baptism in the Jordan] with their children when they are three or four years of age. For their bishops and presbyters fill a vessel with water and read over it, and then they make the child dive into it. This being done, the child is christened. This is what our Prophet says: 'Every child is born in the state of original purity, but then its parents make it a Jew, or Christian, or Magian.'

The topic of ecumenical councils, or synods, of the Melchite church, six of which are commemorated on 21 April, likewise calls for an explanation. The church's hierarchical structure encompasses nine ranks whose titles indicate clerical degrees, all the way from the lowest, cantor, to the highest, patriarch.

Synod means a meeting of their wise men, of their priests, bishops and other church dignitaries, for the purpose of anathematizing some innovation, for something like cursing each other or for the consideration of some important religious subject. Such synods are not convoked except at long intervals, and if one takes place, people keep its date in memory and frequently celebrate the day, hoping to obtain a blessing thereby and wanting to show their devotion.

Al-Biruni's emphasis on Melchite synods appears to indicate his opinion that Islam does not have the equivalent of such clerical structures nor such meetings of the wise men that would provide an institutional setting for doctrinal decisions and their cursing each other.

In his exposition of 'the Christian Lent and those feasts and festive days which depend upon Lent and revolve parallel with it through the year, regarding which all Christian sects agree among each other', al-Biruni can refer back to the many calculations and tables he had put forth on the subject of Jewish Passover, because Christian Lent 'is one of the institutions dependent on Passover, and is in more than one way connected with it'. Easter is the first Sunday following the first full moon after the vernal equinox observed by eyesight and must follow (not coincide with) Passover, meaning that it must fall between 22 March and 25 April. The beginning of Lent will therefore occur between 2 February and 8 March. Al-Biruni is knowledgeable about some of the paschal controversies in the Christian Church, such as quartodecimanism (that Easter should be observed on a fixed date, the fourteenth of the lunar month of Nisan, 14 April) and quintadecimanism (that Easter should be observed on the Sunday following 14 Nisan). He also knows about divergencies in the different methods of determining the paschal moon (where the Antiochians followed Jewish reckoning and the Alexandrians did not). The only tables that al-Biruni provides for the Melchites are attributed to the first Council of Nicaea (525 CE) and Bishop Eusebius, who had decided in favour of the Alexandrian paschal cycle.

Al-Biruni's chapters on the Jewish and Christian calendars are noteworthy not only for the scientific rigour of his research but also for the absence of any polemics or value judgements on the religions themselves. Within his elitist paradigm of a unified world civilization (see Chapter 5), al-Biruni's inter-religious competencies came as offers to help correct the various religious calendars. In the name of science, for example, he identified errors in both the Jewish calculation of Passover and the Christian calculation of Easter, and so he amended and corrected the Passover and Easter calculation tables while taking the doctrinal traditions of each religion into consideration:

> Since it has been our object hitherto to point out scientific truth, to mediate between the two parties [Jews and Christians], and to adjust their differences, we have put forth the methods of each of the two sects according to their own theory as well as that of others, so as to show to each of them the *pro* and the *contras* of their case. And from our side we have proved that we candidly adopt their tradition and lean upon their theory, in order to make the truth clear to them. In all of which we are guided by the wish that both parties should dismiss from their minds the suspicion that we are partial to any side or try to mystify them; that their minds should not shrink back from our opposition, when we pass in review the [chronological] canons which they produce. For if they are left such as they are, they are not

free from confusion and mistakes, most of which we have already pointed out.

One wonders whether he expected gratitude or even acceptance of his efforts by the two communities. Probably not. For al-Biruni, science was service to God and to His Creation, and it was both ‘clearer’ and ‘truer’ than many of mankind's more muddled cultural constructs.

Al-Biruni's Chapter on the Days of the Greek Calendar as Known among Both the Greeks and Other Nations

This section of *The Chronology* derives from vastly different sources. It follows the format of an old Arabian pagan star calendar (the *anwa'*, mentioned in Chapter 2) that later survived as a literary genre on the rising of specific stars or constellations (lunar mansions) and their influence on the local climate; in al-Biruni's hands, this lore becomes a *tour de force* of natural and social science presented in the form of a farmer's almanac that lists the weather, celestial events, agricultural traditions and cultural customs by date in a solar calendar used by ‘the Greeks and Syrians and all who follow their example’ and starts on 1 October. Al-Biruni quotes the months ‘by the names of the Syrians only, because they are generally known among the people’.

The information comes from the works of Hellenistic scholarship as well as a host of Arabic, Persian, Indian and other regional sources on geography, astronomy, medicine, history, mythology, folk traditions and superstitions and the like. Al-Biruni indicates that he has incorporated into his text the *Kitab al-anwa'* of Sinan ibn Thabit (d. 942/943), son of Thabit ibn Qurra (d. 900/901). Both father and son had hailed from Harran in Syria, a bastion of ancient Greek learning, and both were famous for their work in philosophy, mathematics and medicine. In the *Kitab al-anwa'*, Sinan had made a collection of meteorological observations that he compiled from ancient sources and enriched with the observations of his father and his own. Sachau opined that by incorporating this work into *The Chronology*, al-Biruni ‘has preserved to us the most complete *Parapegma* of the ancient Greek world’.

The chapter sparkles with information that might enliven a highbrow dinner gathering of educated individuals from different professions and proves that in addition to the seriousness of the scholar, al-Biruni would have held his own in polite society. One can find a similar enthusiasm for all aspects of life, including the brilliantly bizarre, in the prose and poetry of the great literary figures of his age. In Arabic cultural history, this phenomenon is referred to as *adab*, which in the language of the classical period meant something like ‘good habits, good breeding, refinement of manners, social graces’, as well as the literature that teaches such behaviour. Today, *adab* is mainly just ‘literature’. By contrast, the classical concept was an educational blueprint for the members of elite society slated to include personal experience, linguistic brilliance, mastery of large amounts of past and present textual knowledge and some personal wisdom. Tarif Khalidi has likened *adab* to the Greek educational ideal of *paideia*, an individual's ‘training of the physical and mental faculties in such a way as to produce a broad enlightened mature outlook harmoniously combined with maximum cultural development’. We should perhaps also liken this classical Arabic *adab* to the later cultural ideal of *humanism* of the European Renaissance, since both were enriched by a revival of classical letters, an individualistic and critical spirit, and a shift of emphasis from religious to secular concerns. This new spirit changed the tenor of literary production.

What sort of data would a *calendarium* of this genre offer the reader? Here follow a few more or less randomly selected examples, all of which al-Biruni quotes by the Julian calendar.

Beginning with 26 February, he lists seven consecutive days of severely cold weather; the Arabs had a special name for each of the days, while they referred to their group as ‘Old Woman's Days’ (a much-debated name) that marked the end of the cold season:

> Nobody should be astonished at the fact that the cold towards its end, when it is about to cease, is the most severe and vehement. Quite the same is the case with the heat, as we shall mention hereafter. Similar observations you may make in quite common physical appearances. E.g. if the lamp is near the moment of extinction, because there is no more oil, it burns with an intense light, and flickers repeatedly, like the quivering [of human limbs]. Sick people furnish another example, especially those who perish by hectic fever or consumption, or the disease of the belly, or similar diseases. For they regain power when they are near death; then those who are not familiar with these things gain new hope, while

those who know them from experience despair.

Under 17 March, al-Biruni does not mention Saint Patrick or Ireland (of Europe he knew very little), but he does mention that

> on this day the snakes open their eyes, for during the cold season, as I have found them myself in Khwarizm, they gather in the interior of the earth and roll themselves up one round the other so that the greatest part of them is visible, and they look like a ball. In this condition they remain during the winter until this time.

The date of 17 March (in a leap year) or 18 March (in a common year) is also the day of the first (vernal) equinox that signals the beginning of the Persian spring (see below). Likewise, the Hindus celebrate it as 'their Nawruz', a great day of prayer and feasting and gift giving among them that has magic portents for health and well-being. Further, on 17 March

> the crocodile in Egypt is thought to be dangerous. The crocodile is said to be the water-lizard when it grows up. It is an obnoxious animal peculiar to the Nile, as the sking is to other rivers. People say that in the mountains of Fustat there was a talisman made for that district. Around this talisman the crocodile could not do any harm. On the contrary, when it came within its limits, it turned around and lay on its back, so that the children could play with it. But on reaching the frontier of the district it got up again and carried all it could get hold of away to the water. But this talisman, they say, has been broken and lost its power.

The date 28 July is the day when Caliph Abu Ja'far al-Mansur began to build Baghdad. This was in Aera Alexandri 1074 (the caliph moved into his new city in AH 145, 762 CE). It was the astrologer Nawbakht who determined the optimal time for the commencement of all building activity, and al-Biruni here adds a schematic chart of 'the constellations which heaven showed at the time, and the stations of the planets, which appeared on heaven'.

Our modern equivalent to al-Biruni's 'Greek calendar' would be something like *The Old Farmer's Almanac*; founded in 1792 in the footsteps of Benjamin Franklin's 1732 *Poor Richard's* series, the yearly copy of the almanac is now available in most hardware stores. Still a form of folk literature, it offers a mixture of weather predictions, astronomy, astrology, food, gardening, health and farm and fishing lore that represents some real science and some bizarre superstitions side by side.

Al-Biruni on Eras in the Persian Calendar

Ancient Iran was Zoroastrian. Al-Biruni explains that 'the Persians in the time of Zoroastrianism used to date successively by the years of the reign of each of their kings. When a king died, they dropped his era, and adopted that of his successor.' The Achaemenid emperor Artaxerxes (d. 359 BCE) came to power in 389 BCE, and on 3 March 389 BCE a new era was instituted that used the Egyptian calendar of 12 months with 30 days each, adding either five or six epagomenal days at the end; each of the 30 days of the month was given a name. It appears that this model was not pervasive because at some point 'the Zoroastrians' opted to go with 12 30-day months per year and intercalate an extra month of 30 days every 120 years, which adjusted the average length of the year to 365 1/2 days.

After many other regnal epochs had been instituted and had passed, a new era began on 16 June 632 CE on the accession of the last Sassanian emperor, Yazdigird III (d. 651 or 652), who was then only a child. This calendar also had 12 months of 30 days each; the epagomenal days were inserted not after the twelfth but after the ninth month. Eventually there were problems with this calendar of Yazdigird III, which al-Biruni sums up by saying that it was 'based upon Persian non-intercalated years'; his critique hinges on Sassanian negligence and, later, Umayyad and Abbasid tardiness in keeping (or bringing) the Persian year in sync with the planting and harvesting and taxation seasons that were supposedly regulated in accordance with the empire's fiscal, seasonal calendar based on the solar year.

Here follows a summary of al-Biruni's story of the era of the reign of Yazdigird, which is based upon Persian nonintercalated years. Yazdigird ascended the throne 'when his empire had been shattered, when the women had got hold of it, and usurpers had seized all power'. Most of the battles of the Caliph Umar ibn al-Khattab (d. 644) in Medina were directed against him. Finally, the empire

succumbed, and he was put to flight and killed by a local satrap in the house of a miller in Marw. The memory of his romantic life and sad end still resonates to such an extent that the Parsees, who emigrated to India but remained true to their religion and the traditions of their country of origin, date the beginning of their era from the day of his coronation.

The Persian calendar was reformed by the Abbasid Caliph al-Mu'tadid (d. 902), who based it on 'Greek' (solar) years and Persian months, with the difference that every four years one day was intercalated. Al-Biruni explains the reasons for the Abbasid calendar reform and its various stages as follows: the Caliph al-Mutawakkil (d. 861), while wandering around his hunting ground, observed corn that had not yet ripened. He then questioned how the people could be required to pay their taxes at this time and was informed that this had indeed placed considerable hardship on the population, including debts, foreclosures and forced migration. Upon enquiring whether this was a recent occurrence, he was told that the problem went back to an old regulation by 'the Persian kings', maintained and enforced by 'the kings of the Arabs', that taxes should be levied at Nawruz (Noruz), that this order had originally worked quite well, but that for many years now the corn had not yet been ripe by the date of Nawruz. Already under the Umayyad Caliph Hisham ibn Abd al-Malik (d. 743) there had been consultation on whether to intercalate a month into the Persian calendar to postpone the date of Nawruz, but Hisham had declined, saying that he was afraid to violate the Qur'anic injunction against intercalation (Qur'an 9:37: 'intercalation is but an increase in unbelief' or 'intercalation is an addition to disbelief').

Later, at the time of Caliph Harun al-Rashid (d. 809), the landowners had appealed to his Persian vizier Yahya ibn Khalid ibn Barmak (who fell from favour in 803) to postpone the date of Nawruz by two months; the Barmaki was initially in favour of this request but then dropped the matter when his enemies accused him of 'secretly adhering to the religion of Zoroastrianism'. Eventually, the Abbasid Caliph al-Mutawakkil (d. 861) ordered Ibrahim ibn Abbas al-Suli (d. 857), a famous poet and high official at his court, to design a new, fixed calendar in which Nawruz was postponed until 17 June. The caliph also ordered him to compose a paper, or edict, on the postponement of Nawruz and to send it in the Caliph's name to all the provinces of the empire. This occurred in April 857. Then al-Mutawakkil was killed, and his plan was not carried out until the reign of al-Mu'tadid (d. 902), who paid the matter much consideration. But al-Mu'tadid's scholars calculated the matter differently and arrived at 11 June, not 17 June, as the date for Nawruz, legislating further that thenceforth the years of the Persian calendar were to be intercalated exactly in the manner of the Greeks.

Al-Biruni calculates that al-Mu'tadid's reform did not return Nawruz 'to the place which it [had] occupied at the time when intercalation was still practised in the Persian empire'. Indeed, even though there is 'much uncertainty and confusion in the Persian chronology', the Persians had apparently already begun to neglect their intercalation nearly 70 years before the death of Yazdigird III. Al-Biruni opines that under al-Mu'tadid, it would have been necessary to postpone Nawruz not by 60 but by 77 days, 'in order to restore it to its original place of June 28'.

At issue here may be more than one calendar, each with its own 'New Year's Day'. To al-Biruni's understanding, the Persian new year begins with a New Year's Day called Nawruz, and he quotes many different explanations of how this name came about. He indicates that by his time, the day fell on the date of the vernal equinox (on or around 17 March of the Julian calendar), but its older place had been at the summer solstice (on or around 17 June of the Julian calendar). According to al-Biruni, the latter date had been much easier to determine through simple observation of shadow lengths, while precise determination of the equinoctial day now required knowledge of geometry, astronomy and the use of special instruments of observation. The summer solstice is 'the time of the ripening of the corn. Therefore it is more proper to gather the taxes at this time than at any other.' Nawruz used to be at the time of the rising of Sirius, 'but now Nowruz has receded from its original proper place and now coincides with the sun's entering into the sign of Aries and which is the beginning of spring'.

Did al-Biruni really claim that Nawruz was originally celebrated at the time of the summer solstice? Or did he make a connection between the beginning of an Iranian civil calendar (in March) and the beginning of an Iranian fiscal or tax calendar (in June), calling them both New Year's Day? At times, several calendars coexisted in Iran, which differed in their intercalation rates and presumably also their starting dates. For example, it appears that the Sassanians introduced a new solar-year-based 'land tax' (*kharaj*) in or around 611 CE that stayed operational even after the coming of Islam. In addition, Yazdigird III's era began on the day of his coronation, 16 June 632, a date close to the summer solstice. Indeed, some of the uncertainties and confusions in Persian chronology must be

ascribed to the concurrent use of different calendars for different purposes, including the fact that several of the calendars later introduced in the Islamic period were adaptations of ancient Iranian systems, while foreign influences also continued to be assimilated into indigenous practises and requirements. In any case, it appears that Nawruz meant several different things to al-Biruni in his accountings of the Iranian calendar: first, the 'New Year's Date' of any Iranian dynastically defined calendric era (where his latest model was that of Yazdigird III, 16 June 632); second, the 'New Year's Date' of one or more older Iranian administrative calendars that had traditionally regulated the taxation schedule; and third, the classical Iranian concept of Nawruz as the festival to celebrate the vernal equinox and thus the arrival of spring. The fact that al-Biruni used the multilayered meanings of Nawruz in the Persian calendar without commenting on these differences suggests his assumption that everybody knew what he was writing about. Certainly, Nawruz, 'the spring festival' of the vernal equinox, was celebrated in al-Biruni's time, and he mentions some of the many rituals and festivities that surrounded it in Iran and India.

Modern studies of the Persian calendar as well as newsletters and web pages of Iranian cultural associations enhance and update al-Biruni's descriptions. Nawruz starts at the precise instant when the sun (in its apparent annual course around the earth in the sky) coincides with the vernal equinox, an event that can occur at any time during the 24-hour diurnal period. (Modern calculations of the equinoctial event for the Gregorian interval AD 1583–2500 indicate that 584 equinoxes, or about 64 per cent of all of the events, occur on 20 March [Gregorian calendar] for the Tehran longitude.) According to long-standing tradition, the Iranian year begins at midnight. Therefore, the new year must begin at the midnight closest to the instant of equinox. In the olden days, that moment was announced by cannon shots or fifes and drums; nowadays, it is mainly relayed by TV and radio stations and on the internet. Regardless of the technology, all celebrants await the event dressed in holiday clothes, and when it has arrived, they rejoice and cheer and welcome the new year. Persian tradition has long upheld that both the celebration and the date of Nawruz go all the way back to the first Persian Empire or even earlier. The 'New Day', symbolizing the return of the sun and the rebirth of nature after a barren winter, is a Zoroastrian legacy. In the several days or weeks before and after the spring equinox, there is house cleaning and seed sprouting, the lighting of (and sometimes jumping over) fires and picnics in the verdant countryside. Internet web pages have taken to describing some of the rituals and also the foods that symbolize hopes and prayers for the new year; an integral part of the celebration is the *Haft-Sin* ('seven *S*'s') table that is set up to contain seven auspicious things whose names start with the letter *S*. The festival remains a strong feature of Persian national identity both within Iran and among the larger Persian diaspora; it is also said to be celebrated by Afghans, Azeris, Caucasians, Kazakhs, Kurds, Kyrgyz, Tajiks and Turkmens.

We have to move 49 years beyond al-Biruni's death to ascertain what happened to the Yazdigird solar calendar. (Surely, al-Biruni would have liked to have been involved.) The calendar was reformed in Iran between 1074 and 1079 CE by the famous astronomer and poet Omar Khayyam (d. 1123) and seven other astronomers who carried out astronomical observations and calculations at the court of the Seljuk Sultan Jalal ad-Din Malik Shah (d. 1092) at the behest of his Persian vizier Nizam al-Mulk (d. 1092). Part of the reason for the reform was that by 1075 CE, the Persian new year had fallen on 27 February, whence the Sultan and his advisers charged the astronomers to devise a calendar by which the next Nawruz would be celebrated in the spring. The resulting calendar was called the Jalali calendar in honour of the Sultan and was similar, but not identical, to the 'Seleucid' Alexandrian/Egyptian matrix of the Yazdigird calendar, except that its intercalation system was infinitely more sophisticated. (The length of Omar Khayyam's solar year was later correctively adjusted at the Ilkhanid ruler Hulagu's observatory in Maragha, Azerbaijan, by the famous astronomer and mathematician Nasir al-Din al-Tusi [d. 1278].)

The Jalali era officially began on Nawruz, 15 March in the Julian calendar (21 March in the Gregorian calendar) of the year 1079 CE (corresponding to 9 Ramadan AH 471). In 1584 CE, Sultan Akbar, son of Sultan Babur, founder of the Moghul dynasty, took the Jalali calendar to India, where he retroactively gave it a new starting date, the Nawruz, after his own accession to the throne, in 1556. This calendar was still in use in India until the accession of Shah Jahan in 1628, but eventually and gradually it fell into disuse.

The present-day Iranian reformed calendar (or whatever is left of it) was instituted by Reza Shah Pahlavi in the 1920s. The epoch of the era is the Nawruz (Gregorian 21 March) of 621, a few months ahead of the epoch of the standard Islamic (Hijra) year, which is 16 July. At present, for example, the year 2013 CE on and after the March equinox corresponds to the Persian year 1392. (On the epoch,

‘starting date of an era’, see chapter one; E. G. Richards reminds us that ‘epochs should be used with care when converting dates from one era to another: in some cases the years counted vary in length, and in others they start in different seasons’.) On 31 March 1925, the Iranian parliament decreed that this combination between the Jalali solar year and the Hijra era was to be the Iranian national calendar, and it appears to have remained in force except for short periods of interruption. In Iran, the Persian calendar coexists, and at times collides, with the Islamic lunar Hijra calendar, such as when religious and national–cultural festivals compete with each other for attention.

Al-Biruni on the Festivals of the Muslims

In this brief and unevenly sketchy chapter on the Islamic calendar, al-Biruni reviews specific dates in the 12 lunar months of Hijra chronography under the heading of ‘The Arabs Celebrate the Following Days of Their Calendar’. The occasions listed for commemoration are a mixture of the doctrinal and the political; noteworthy is the emphasis that he places on the celebrations of early Shi‘i martyrology, especially Husayn's martyrdom and the perfidity of his Umayyad foes. Since the events are not chronologically separated, except by day of occurrence and commemoration, they appear simultaneous; the calendar of feast days is thus a dense web of holy events where history and eschatology coexist. Here follows an abbreviated version of al-Biruni's calendar of ‘Arab feast days’.

Prominently listed under *al-Muharram*, the first month of the (lunar) year, is the feast of Ashura, which falls on the tenth day of the month. Originally considered a blessed day, on which God had bestowed mercy on Adam, it came to be considered an unlucky day after the murder of the Prophet's grandson Husayn ibn Ali ibn Abi Talib in Karbala (680 CE), ‘when he and his adherents were treated in such a way as never in the whole world the worst criminals have been treated. They were killed by hunger and thirst, through the sword; they were burned and their heads roasted, and horses were made to trample over their bodies.’ The day is a day of public mourning for the people of the Shi‘a who lament and weep in Baghdad and other cities and villages and make a pilgrimage to the blessed soil (the tomb of Husayn) in Kerbela. In contrast, the Umayyads decked themselves out in new garments and celebrated the day with banquets and parties; ‘such was the custom in the nation during the rule of the Banu Umayya, and so it has remained also after the downfall of this dynasty.’ According to pious legend, all of the following events likewise occurred on Ashura: God had mercy on Adam, the ark of Noah stood still on the mountain al-Judi, Jesus was born, Moses was saved from Pharaoh and Abraham from the fire of Nebuchadnezzar, Jacob regained his eyesight, Joseph was drawn out of the well, Solomon was invested with royal power, the punishment was lifted from the people of Jonah, Job was freed from the plague, and Zachariah's prayer was answered and John was given to him. Even though al-Biruni avers that all those events could possibly have occurred on that date, he considers the information unreliable because it rests only on the authority of popular storytellers, the *qassas*, ‘who do not draw upon learned sources nor upon the agreement between the owners of a divine writ’ (the Jews and Christians). Al-Biruni then examines the theory that both name and practise of Ashura are loans from Judaism, since the Jews in Medina were fasting the Ashur, the tenth day of the first month of their year (Tishri), when the Prophet first arrived there after the Hijra (622 CE) on a Monday, and he was told that they did this because on this day God had drowned Pharaoh and saved Moses and the Israelites. Proclaiming that ‘we have a nearer claim to Moses than they’, Muhammad then also fasted and ordered his followers to do the same, until fasting was later made obligatory for the month of Ramadan and the Ashura fast ceased to be obligatory. According to al-Biruni, this story is untrue because the calendar dates of Jewish Ashur, Islamic Ashura and the Prophet's arrival in Medina do not match; in addition, the assertion that on this day God drowned Pharaoh ‘is refuted by the Torah itself’. Thereafter, on the sixteenth day of Muharram, Mecca was made the *qibla* of the Muslims (624 CE, replacing Jerusalem). On the seventeenth, the ‘Companions of the Elephants’ (Ethiopians from the South of Arabia) arrived before Mecca (570 CE, year of the Prophet's birth?) to conquer it, which they were incapable of doing.

Of the second month of the year, Safar, the first day commemorates how Husayn's severed head was brought to Yazid ibn Mu'awiya in Damascus who struck out the foreteeth (the central four incisors) with a stick while reciting a poem that with this death (of the Prophet's grandson, scion of his lineage), he had avenged for all his own kin slain during the battle of Badr (624 CE, the first military victory of the Prophet over the pagan Meccans). On the sixteenth day of the month was the first appearance of the Prophet's final illness. On the 20th, Husayn's head was again laid with the body, and both were buried together. On the 24th, the Prophet and Abu Bakr (companion and later

first caliph) left Mecca and concealed themselves in a cave.

Rabi' I, the third month of the year: On the first day of this month, the Prophet died (632). On the eighth, he arrived in Medina after the Hijra (622). On the twelfth, he was born on a Monday in the Year of the Elephants.

Rabi' II, the fourth month of the calendar: On the third day of this month, the Ka'ba burned down when (the Umayyad general) al-Hajjaj ibn Yusuf attacked Mecca (693) and besieged (and eventually killed) Abdallah ibn Zubayr (son of one of the Prophet's companions and rival to Yazid ibn Mu'awiya's caliphate; actually, the Ka'ba had already been torn apart and burned in 683 during the previous siege by the Umayyad general al-Husayn ibn Numayr). On the fifteenth of the month of Rabi' II was the birth of Ali ibn Talib (Muhammad's first cousin on his father's side and son-in-law by marriage to Muhammad's daughter Fatima).

Jumada I, the fifth month: On the third day of this month was the battle of the Camel in (or near) Basra (656 CE), where Ali defeated Muhammad's widow A'isha bint Abi Bakr and her allies, the Prophet's companions, Talha and al-Zubayr. On the eighth was the death of the virgin Fatima (Fatima the Pure), the Prophet's daughter.

Jumada II, the sixth month: On the second day of this month was the death of Abu Bakr (companion and later first Caliph, who died in 634 CE). On the fourth, Fatima was born of Muhammad's first wife, Khadija bint Khuwaylid.

Rajab, the seventh month: On the fourth day of this month, Ali and Mu'awiya, rivals for the caliphate, met at the battle of Siffin (657 CE). On the 26th, God made Muhammad His Prophet to all mankind (610 CE?). The 27th was the night of the Prophet's ascension (*mi'raj*) and the night journey (*isra'*) to Jerusalem.

Sha'ban, the eighth month: On the third day of this month was the birth of Husayn, son of Ali. On the fifteenth, the Ka'ba was made the *qibla* instead of Jerusalem.

Ramadan, the ninth month, is the month of obligatory fasting. (Depending on the moon, either or both of Sha'ban and Ramadan can last for 29 or 30 days, meaning that the reported prophetic Hadith that Ramadan is always a 'full month' of 30 days is not correct.) Husayn, son of Ali, was born on the sixth day of Ramadan, according to most authorities. On the tenth, Khadija died. On the seventeenth, Ali was martyred when 'the cursed Abd al-Rahman ibn Muljam al-Muradi struck him on the head so as to injure the brain' (661 CE). Also on the seventeenth, a Monday in the second year after the Hijra, was the battle of Badr (624 CE). On the nineteenth was the conquest of Mecca (630 CE). The Prophet did not perform the pilgrimage at that time 'because the Arabian months were back behind real time in consequence of the *nasi'* [postponement of certain months in the times of heathendom]. Therefore he waited till the months returned to their proper places, like on the day God created heaven and hell, and then he performed the farewell pilgrimage [also called the 'correct pilgrimage'], and forbade us to use the *nasi"* (see Chapter 2). On the 21st was the death of the Prince of the Believers, Ali ibn Abi Talib, and also of several others among the imams (of Twelver Sh'ism's Holy House). On the 25th, Abu Muslim Abd al-Rahman ibn Muslim first raised the standard of the Abbasids in Khorasan (747 CE, prior to their overthrow of the Umayyads in 750 CE). The 26th is the date of some later uprisings in central Asia. The 27th of the month is *Laylat al-Qadr* ('the Night of Power', of which Qur'an 97:3 says that it 'is better than a thousand months'), even though its real date is not known and could be the night of the seventeenth or the nineteenth. According to Qur'an 2:185, the Qur'an was sent down in the month of Ramadan; Qur'an 8:41 specifies 'the revelation We sent down to our Servant on the day of *al-furqan* [the testing], the day when the two hosts met' (at Badr?), so perhaps it was on the seventeenth, or – according to other traditions – it could be the 24th.

Shawwal, the tenth month: its first day is the feast of fast breaking (which concludes the fasting of the month of Ramadan), also called the day of mercy. God selected Gabriel on this day as the bearer of His revelation. He also inspired the bees and taught them how to make honey (see Qur'an 16:68). People maintain that on this day God created Paradise, but to al-Biruni reports of this nature suffer from inadmissible anthropomorphisms, such as that God planted the tree Tuba with His own hand. The third day of Shawwal brings the beginning of a voluntary fasting period of six consecutive days. On the fourth day, Muhammad and the Christians of Najran argued with each other. On this date, the Prophet installed (his grandsons) Hasan and Husayn in the right of sons of his and (his daughter) Fatima in the right of his wives, and Ali ibn Abi Talib he made his intimate friend. On the seventeenth was the battle of Uhud (625 CE), even though some say that it occurred in the middle of the month. In

this battle, the Prophet's uncle Hamza was killed, and Muhammad lamented his loss. On the nineteenth, Ali ibn Talib died. On the 28th, Jonah was devoured by the fish.

Dhu al-Qa'da, the eleventh month of the calendar: On its fifth day, 'the Ka'ba was sent down. God took compassion on Adam.' (According to Qur'an 3:96, 'the first House [of worship, on earth] that was founded for the people is that in Bakka, a blessed house and a guidance for the worlds'; in pious legend, the very beginning of the Ka'ba is associated with a tent [of red jacinth] in which Adam lived after his banishment from Paradise, around which he now performed the *tawaf* [circumambulation] following the examples of the angels in heaven who circumambulated God's Throne; after Adam's death, his descendants built the Ka'ba, but according to most authorities, it was destroyed during the Deluge, so that only a small mound of red earth was left, while the angels had concealed the sacred stone – which was then white – in the mountain Abu Qubays.) The fifth day of Shawwal is also the day when 'Abraham and Ishmael raised the foundations of the House' (Qur'an 2:127). (According to pious legend, Abraham the patriarch arrived in Arabia led by the *sakina*, which came in the shape of a stormy wind with two heads; some say that it had a snake's head. When it reached the Ka'ba, it wound itself around its foundation and said 'build on me'; else, Abraham built on its shadow. Ishmael helped him to build the Ka'ba, after which the angel Gabriel returned the sacred stone from Abu Qubays, and Abraham placed it in the new structure.) On the fourteenth of the month, 'Jonah, they say, came forth from the belly of the fish. According to this view, he must have stayed there twenty-two days, whilst according to the Christians he stayed only three days, as is mentioned in the Gospel.'

Dhu al-Hijja, the twelfth month of the year, is the month of the Hajj. On the first day of this month, the Prophet married his daughter Fatima to his cousin Ali ibn Abi Talib. The first ten days of the month are called 'sacred days'; this is perhaps in commemoration of Qur'an 7:142, God's promise to Moses of 40 nights (of communion) with his Lord (in the Sinai): 'thirty nights' (which are the nights of Dhu al-Qa'da) 'and to complete the term with ten more' (which are the first ten days of Dhu al-Hijja). The eighth day of the month is called *al-tarwiya* ('to quench someone's thirst') because water was available to the pilgrims at this time or because God made the well of Zamzam spring forth on this day for Ishmael to quench his thirst or because God revealed Himself to the mountains, in the history of Moses. The ninth day is called *arafa* ('to know, to recognize'), which is the day of the great pilgrimage on (Mount) Arafat. It is so called because people recognize each other at the time when they assemble for the performance of the rites of pilgrimage or because Adam and Eve recognized each other in the place of Arafat, after they had been driven out of Paradise. On this day, God selected Abraham as a friend (*Khalil*). It is also called the day of forgiving. The tenth day of the month is called the day of the victims, because on this day the animals that had been brought to Mecca to be sacrificed were slaughtered. It is the last day of the pilgrimage. On this day, Isaac [*sic*] was ransomed with the ram. On this day the 'Road to the Last Judgement' is said to have been created. The eleventh day of the month is called the day of sojourning, because on this day people sojourn in Mina. The twelfth day is called the day of going away, because on this day the people hurry away from the holy district. On the eleventh, twelfth and thirteenth, the meat of the sacrificed animals is cut into pieces and exposed to the sun for drying. On the seventeenth, Uthman ibn Affan (companion and later third caliph) was killed (656 CE). The eighteenth is the Day of Ghadir Khumm, name of a station on the road where Muhammad stopped on his return from the farewell pilgrimage and formally requested his followers to befriend and support Ali as they were befriending and supporting the Prophet himself. On the 24th, Ali gave away his seal ring in charity during prayer. On the 25th, Umar ibn al-Khattab (companion and later second Caliph) was killed (644 CE). On the 26th, David was inspired to ask for pardon (Qur'an 38:24).

This youthful primer on the 'festivals of the Muslims' is an incomplete and sometimes contradictory document, either because the author left much of the information blank or perhaps because portions of the text were lost in transmission. In its present form, the chapter does convey that al-Biruni was knowledgeable about the Qur'an and that he was aware of some of the issues that underlay different theological and legal positions in the formal scholastic discipline of *tafsir* (Qur'anic exegesis). In addition, he had clearly been exposed to various popular legends of the sort that an ordinary *kuttab* (Qur'an school) or a tutor of that background would have conveyed. As previously noted, this part of his intellectual formation probably occurred in a Shi'i or pro-Shi'a environment. Other than that, his 'calendar of sacred events' is quite minimalist: there are some of the old prophets, there are Mecca and the Ka'ba, Muhammad's biography, the *Rashidun* caliphs, the Umayyads and one glimpse of the Abbasids. This document may be of greater interest to us by reason of what it does *not* contain; perhaps, though, we should also consider that, even as a young scholar, al-Biruni abbreviated his

research and writing on the topics that he assumed were too well known or that were of little interest to the scientist or both.

Conclusion

Al-Biruni's *Chronology* contains many more chapters and sections of chapters, diagrams and listings on epochs and eras, seasons of ritual and worship, feast days, periods of commemoration and mourning and other forms of cultural manipulations of time than I have here presented. We should recall that al-Biruni wrote *The Chronology* when he was 27. It was his first major work, and he did get some details wrong – like the definition of the 'era of Alexander' that he wrongly pegged to Alexander (the Great) of Macedonia instead of the ruler Alexander IV (Aegus). The Seleucids instituted this calendar in the West of their empire in 312 BCE and in the East in 311 BCE. Later, as previously noted, it was adopted by the Syrian churches, which continued to use it, probably also coining the name 'era of Alexander' that in turn was adopted by Muslim scholarship. Al-Biruni later corrected his error in his more mature writings, such as his *Canon Mas'udicus*. Still, what exuberance the text of *The Chronology* conveys as its author assembles his many dynastic, mathematical and theological data to show the richness of the human imagination in its encounter with time. Science can be made palatable to the educated reading public:

> Now, if we in some places wander about through various branches of science, and plunge into subjects which are not very closely connected with the order of our discussion, we must say that we do not do this because we seek to be lengthy and verbose, but as guided by the desire of preventing the reader from getting tired. For if the mind is continually occupied with the study of a single science, it gets easily tired and impatient; but if the mind wanders from one science to another, it is as if it were wandering about in gardens, where, when it is roving over one, another one already presents itself; in consequence of which, the mind has a longing for them, and enjoys the sight of them; as people say, 'Everything that is new offers enjoyment.'

PART III

HOW DAILY MUSLIM RITUALS ARE STILL PERFORMED 'ON TIME'

CHAPTER 7

‘TIME STICKS’:REGULATING THE ISLAMIC DAY

To al-Biruni, the *day* is the only unit of time that is universally recognized; all cultures have used it as a common building block in their much varied larger constructions of time. In the chapter on eras in *The Chronology*, al-Biruni writes:

> I shall explain the intervals between the epochs of the usual eras by a measure which is counted in the same way by all nations, i.e. by days; for, as we have already mentioned, both years and months are differently measured.

Yet different cultures have also done very different things in defining both the beginning and the end of their ‘day’, and also their days' constituent parts, the ‘hour’.

Times of the Day

In the three Abrahamic religions, Judaism, Christianity and Islam, the day begins at sundown. Even when the official calendar indicates otherwise, this ancient monotheistic tradition continues to resonate in Christian liturgy and maintains its hold on Jewish timekeeping. In the case of Islam, things can get even more complicated, because the dusk-to-dusk pattern of the traditional Islamic day also runs into the cyclical nature of the Islamic lunar month, where some months last 29 days and others 30, and Islamic law requires eyewitness testimony to the sighting of the new moon to establish their progression.

Since the Islamic day begins at sunset, the night (*layl*, *layla*) is therefore the first part of *yawm* (‘full day’) (except that *yawm* can also signify ‘daylight hours’, that is, the daylight portion of the 24-hour ‘full day’). The convention to use the arrival of night as the date line fits well with the preeminence of the lunar cycle in the Islamic calendar as a whole, since the 12 months of the Islamic year, and so also the year itself, are calculated in terms of lunar cycles. To begin the new day at sunset had probably been a pre-Islamic custom. In ancient Egypt, the new day began at dawn. To the Babylonians, it began at dusk. Even though their *natural* day began at sunrise and ended at sunset, and their hours were seasonal, the Romans started their *civil* day at midnight, which is the reckoning that underlay the Julian and now by extension the Gregorian calendar. Since 1925 astronomers have universally counted the day from the midnight hour. When in 1972 radio stations across the world began to broadcast their time in terms of Coordinated Universal Time predicated on Greenwich mean time, it became global practise to start the ‘official’ day at midnight.

The five Islamic ritual prayers endow the day with a specific pulse that remains a vital ‘sign’ of time perception in Muslim societies. In a world of global time zones, atomic clocks and affordable wristwatches, where day and night are measured in 24 hours of equal 60-minute length, the times of these five ritual prayers are pegged to the much older system of seasonal time, and thus the notion of unequal hours. Even when this fact may merely imprint itself on the subconscious of all who dwell within earshot of a mosque's *adhan* (call to prayer), it fosters a groundedness in the seasonal progression from shorter to longer units of daylight and then back again. Societies have lived by this system of time reckoning and time management through most of human history. For millennia, human labour took its cues from local, astronomical time. The day's stretch between dawn and dusk determined the patterns of working, eating, resting and praying. An hour was a 1/12th fraction of the day or night whose length changed with the seasons, not an absolute or constant entity in its own right. Other than in the regions on or close to the equator, the hours of the day would be shorter in the winter months and longer during the summer. This was not a problem for the sequencing of working, eating and sleeping, because lengthening and shortening of the hours came gradually with the progression of the seasons. In the literature, seasonal time with its ‘temporal’ hours is sometimes

referred to as ‘organic’ time, while the fairly recent convention to universally measure the 24-hour day, at any latitude, in equal 60-minute segments is said to be ‘abstract’ time.

Time Sticks

Folk astronomy and simple timekeeping devices that used shadow lengths by day and lunar mansions by night were part of religious knowledge and devotional practise in all premodern Muslim societies. The *shakhis* or *shakhs* (time stick) is a gnomon (indicator) that marks the sun's apparent progression by changes in the length and direction of its shadow. Most cultures at one time or another have used gnomons to measure daylight hours. Many pre-Islamic cultures, including the ancient Egyptian and Babylonian, Chinese, Greek and Roman cultures, used the concept of the time stick to develop shadow clocks and sundials. In the Arab world, very few of these simple time sticks have been preserved. From the literature it appears that they were most often vertical devices, crafted in various sizes and of various materials such as wood or stone, that stood upright in a mosque's courtyard enclosure. In their splendid 1983 account in *San'a': An Arabian Islamic City*, R. B. Serjeant, David A. King and Isma'il al-Akwa report that an example of a traditional *shakhis* has survived in the main mosque of al-Janad, north of Ta'izz in Yemen,

> a stone gnomon about the height of a man, with which the time of day could be reckoned using simple rules originally adopted from Indian astronomy, and the time of the midday and afternoon prayers, both defined in terms of shadow lengths, could also be regulated. In medieval Yemeni almanacs simple tables were sometimes given for reckoning time of night by lunar mansions.

I myself have seen only the remnants of a *shakhis*, in a now-deserted mosque in an abandoned hamlet of mud-brick buildings near the provincial town of Zilfie in the northern Najd (north-central Arabia). Mosque and settlement had been built during the 1920s, when regional villagers temporarily relocated there to escape Wahhabi Ikhwan attacks on their original dwellings. Anyone who has studied the early Hadith on the Prophet's life in Medina has a pretty clear idea of what the first Muslim mosque in Medina looked like. It was an open square surrounded by a doored barrier-wall that the Prophet and his first companions – some of them his cofugitives from Mecca (*Muhajirun*), others his and their helpers in Medina (*Ansar*) – built on the grounds where his riding camel had first come to rest after his entry into Medina, which had signalled to his Medinan hosts and supporters God's choice for the location of their Prophet's new mosque and domicile. On one side they built the dwellings for the Prophet's household. But the main prayer area was just an open square. After a while, prompted by the bitter cold and rains of the winter season, the Prophet and his companions began to erect some large felled palm trunks whose tops they covered with a web of braided palm leaves for a roof; these stood on the square's northern side that faced the *qibla* (direction of prayer). This addition must therefore have been effected before the revelation commanded the Prophet and his followers to turn in prayer no longer northward toward Jerusalem (or perhaps another sanctuary), but southward toward the ancient shrine, the Ka'ba in Mecca. The basic layout in mosque buildings the world over still carries traces of that first Muslim open-air house of worship in Medina, where some columns and a roof would give special distinction to the area closest to the *mihrab* (the marker, or niche, that indicates the *qibla*). Within a generation or two after the Prophet's death, mosque buildings in the newly conquered Fertile Crescent territories became much grander affairs, when a number of older architectural traditions began to influence how the newly arrived Arab Muslim conquerors built their houses of prayer. The building and design of mosques eventually became one of the glories of Islamic architecture and art.

The visit to Zilfie in the Najd allowed me to see a re-creation of what its Arabian builders had understood from the Hadith to have been the form of the Prophet's original mosque. The *liwan* (pillared and roofed area) in this Zilfie oasis house of worship consisted of two rows of round pillars expanding into rough-shaped, double-tiered capitals. The pillars varied in width and appeared to be built of tree trunks covered over with mud that had dried into a hard shell. In each row, their tops were connected lengthwise with tamarisk beams, between which smaller wooden branches had been arranged crosswise to form a ceiling that carried a substantial mud-brick roof. The wall at the rear of the *liwan* was the *qibla* wall that pointed due west to Mecca. It was in the *liwan*'s recesses that this community (like its prototype) had huddled for their prayer lines on cold winter nights or to escape

from the scorching heat of daylight prayers in the summer. And then there was the *shakhis*. On the mosque's eastern, courtyard, side, a flank of stone had been anchored horizontally in the middle of the roof's edge, its remains still visible, that by the location of the place began to cast its shadow onto the open courtyard when the sun had declined from an overhead position. This *shakhis*'s function had clearly been liturgical, serving not for general timekeeping but to determine the beginning and duration of midday and afternoon prayer times as specified by Islamic law.

Prayer Times in the Holy Qur'an

Ritual prayer (*salat*, pl. *salawat*) and its five-daily appointed times (*miqat*, pl. *mawaqit*) evolved on the basis of Qur'anic revelation and Prophetic and communal practise. Among the many Qur'anic exhortations to prayer (*salat*), devotions, glorification and praise (*tasbih, hamdala*), a smaller number include some general directives as to times of day or night for these forms of worship, but without specification that there should be five set daily prayers or prayer times. This fact gave rise to different interpretations among early Islamic legal experts and scholars of scripturalist exegesis, who all used the same Qur'anic verses and Hadith quotations from the same Hadith collections but arrived at divergent legal and exegetical paradigms. Of the time-specific Qur'anic revelations regarding prayer and devotions, the most often quoted are found in Suras 2, 4, 11, 17, 20, 24, 30 and 40.

When arranged in chronological order, that is, by date of revelation to the Prophet from the earliest (*Early Meccan*) through the *Middle Meccan* and *Late Meccan* into the period after the Hijra (*Medinan*), these verses do not appear to indicate a progression or evolution toward five standardized prayer times. The texts legislate the following: 20:130 (*Middle Meccan*): ‘Praise your Lord before the rising of the sun and before its setting, and some times of the night, and at the ends [or: sides] of the day [*atraf al-nahar*].’ A very important text for many interpreters is 17:78 (*Middle Meccan*): ‘Perform the prayer at the inclination of the sun [*li-duluk al-shams*] until darkness of night [*ila ghasaq al-layl*]. And the recitation of dawn [*Qur'an al-fajr*], it is attended [or: witnessed].’ 30:17–18 (*Late Meccan*): ‘God be praised [when you are] in the evening and the morning. To Him be praise in the heavens and on earth. And in the evening [at the declining of the day], and [when you are] at noon.’ 11:114 (*Late Meccan*): ‘And perform the prayer at the two ends of the day, and at early stages of the night.’ 40:55 (*Late Meccan*): ‘Praise your Lord in the evening, and in the morning.’ 2:238 (*Medinan*): ‘Observe the prayers and the middle prayer [*hafizu ‘ala al-salawat wal-salat al-wusta*] and stand before God devoutly.’ 4:103 (*Medinan*): ‘… Prayer is enjoined on the believers at appointed times [or: at fixed times, or: at stated times, or: in a time-related manner, *‘inna al-salat kanat ‘ala al-mu'minin kitaban mawqutan*].’ 24:58 (*Medinan*) (this verse's primary focus is not on prayer times but on domestic etiquette; mentioned are the three periods of the day when domestic slaves and young children are required to ask for permission before entering private quarters): ‘before the dawn prayer’, during the siesta time of the noonday heat, and ‘after the night prayer’.

At an early date, Islamic interpretation had developed a paradigmatic approach to these revelations. From the vantage point of the interpreters, for whom the five daily prayers at their appointed times had come to represent a core obligation of Muslim communal life, the scripturalist time frames provided an ample base in which to ground the five daily prayers, albeit in various ways. For example, Hadith experts, legal authorities and Qur'an commentators disagreed on which of the five canonical prayers of the Muslim ritual represented the ‘middle prayer’ (of 2:238), where no specific time frame is given. Other revelations (such as 20:130, 30:17–18 and 17:78–9) that provided astronomical parameters for times of prayer and devotions were also open to interpretation. From an early date, Muslim exegesis of the Qur'anic directive of 17:78 (to perform the prayer ‘at the sun's incline’, *li-duluk al shams*, ‘until the darkness of night’, *ila ghasaq al-layl*) hinged on the concept of *duluk al-shams*, ‘when the sun inclines’; by identifying the ‘sun's incline’ with the time immediately following the sun's zenith position at high noon, the interpreters established that the period ‘until the darkness of night’ thus encompassed the noon, afternoon, sunset and night prayers, while the ‘recitation of the dawn’ (*Qur'an al-fajr*) (also legislated in 17:78) signified the dawn prayer.

Prayer Times in the Hadith

Well before its compilation into the Six (Sunni) Canonical Collections during the late ninth century, the Hadith had provided the basis and core of legal and exegetical activities. By the eighth century,

the definitions of times of prayer outlined in the Qur'an and Hadith had been standardized on the basis that the Islamic day begins when the sun has set over the horizon. Following divergent preferences in Hadith selection, the early law schools of Sunni Islam showed some, albeit minor, differences on the meaning of Qur'anic passages regarding prayer times. These have remained operative as part and parcel of each school's self-definition, under the legitimizing umbrella of the Sunni consensus-based principle that all divergencies of interpretation among the accepted *madhahib* (schools of law) are representative of scripture-based truth. On the basis of early Hadith reports accepted by all, each school verified that Islamic prayer and prayer times had been institutionalized by divine decree. Al-Bukhari (d. 870) quotes traditions on the authority of several of the Prophet's Companions that the five daily prayers were, in a sense, 'negotiated' (or 'bargained over') with God by the Prophet during his night journey into the heavens, while the times of prayer were taught to the Prophet by the angel Gabriel. Al-Bukhari presents several chapters on *mawaqit al-salat* (prayer times) in the *Sahih*, his collection of authenticated Hadith that is the most prestigious among the six canonical Hadith compendia.

The traditions assembled by al-Bukhari identify daylight-related patterns of the Prophet's prayer practise in Medina in general terms, while several among them also stress the special merit of performing the prayers at their appointed time. The Prophet prayed the noon prayer (*zuhr*) when the sun had passed its highest point in the sky (i.e., crossed the meridian), but he also said that in times of severe heat, the noon prayer should be offered later; the Prophet prayed the afternoon prayer (*'asr*) when the sun was shining into 'A'isha's room without casting a shadow and while sufficient time remained to walk to the outskirts (of Medina) in broad daylight'; the Prophet finished the sunset prayer (*maghrib*) at a time when one could still discern places an arrow's shot away; he sometimes postponed the evening prayer (*'isha*) until a late hour, when a third of the night had passed; and he performed the dawn prayer (*fajr*) when in the waxing light a man could recognize his close neighbour, while the women, who were farther away, would not be recognized on their way home (from the prayer). The Prophet forbade prayer at the exact moments of the rising, culmination and setting of the sun. Prayers offered at these times are said to occur *bayna qarnay al-shaytan*, 'between the horns of Satan', since it is then that the *mushrikun* (polytheists) offer their own. In his book on shadows, presented in what follows, al-Biruni specifically mentions the Harranians, Hindus and Magians among worshippers of astral bodies who adopt such times for worship and prostration.

In a 'second layer of traditions', the Hadith also specifies the first and last limits of prayer periods. In the books of *fiqh* (jurisprudence), time limits for daylight prayers were early on expressed in terms of shadow length. The system as a whole was ascribed to the example of the angel Gabriel, who had taught it to the Prophet at the beginning of his mission. This is how the early Hadith quotes the Prophet's words in these texts of the Hadith:

> Verily Gabriel came to me twice at the door of the Ka'ba and we prayed the noon [prayer] when the shadow is like the rope of a trap [i.e., very thin], then the afternoon prayer when the shadow of anything is the equal of it[self]; then the sunset prayer when the sun falls and the fast is broken, then the prayer of nightfall when the twilight disappears; then the morning prayer when dawn arises and food is forbidden for the one who fasts. On the second day he [Gabriel] prayed with me the noon [prayer] when the shadow of each thing was like unto it[self], like the time of the day preceding for the afternoon prayer; then the afternoon prayer when the shadow of anything is twice itself, then the sunset prayer at its [same] time as the other day; then the last, the nightfall prayer when [i.e., up to] a third of the night had passed; and the morning [prayer] when it dawns. And he said: The prayertime falls in between.

In a contemporary textbook on prayer times according to the four *madhahib* (schools of law) authored by Sheikh Jum'a Makki, a sheikh of al-Azhar University in Cairo and published in 1988, the angel's instruction to Muhammad and the differences in *mawaqit* among the legal schools are still wedded to time-stick technology.

Prayer Times and the Problem of Geographical Latitude

The classical Hadith shows that it was composed or recorded by people who were not familiar with astronomy. Since the limits of two of the daylight prayer periods are defined in terms of the apparent

position of the sun relative to the local horizon, Islamic prayer times depend on the degree of local latitude and also on the local meridian. To regulate the (seasonally fluctuating) prayer times therefore requires that they be defined in terms of shadow increases, not shadow lengths that vary according to degree of latitude, whence Muhammad's Hadith-recorded formula of shadow lengths in Mecca and Medina would be quite inadequate to determine prayer times in other latitudes.

Latitudes

Latitudes connect places that share the same angle of the sun above the horizon at any given time. Solar altitude, always latitude specific, determines the length of shadows. It also determines the length of days; therefore, the latitude where we live marks our seasons and weather reports and, perhaps more than it does now, used to mark our economies. In the knowledge that the earth is round, Hellenistic science had developed the concepts of latitude and longitude and defined them as imaginary lines on the earth's surface. At first the lines existed in the form of (on the whole woefully insufficient) astronomical data based on observation and calculation; later the cartographers, prominent among them Ptolemy, traced them on their (still very flawed) geographical maps. The parallel lines of latitude wrap the globe from the equator to the poles in a pattern of shrinking concentric circles, which to the scientists were markers of the seasonal journeys and positions of the seven planets that moved from east to west across their sky. Since it is at the equator that the seven planets pass almost directly overhead, scientists early on chose the equator as their zero-degree line of latitude. Then they divided the hemispheres above and below the equator into 90° each and calculated and drew the parallels of the Tropic of Cancer and the Tropic of Capricorn that marked the sun's passing through the summer and winter solstices, which they understood to be the northern and southern boundaries of the sun's motion over the course of the year.

Al-Biruni on Prayer Times and Islamic Science in the Service of Religion

As outlined above, from the late eighth and early ninth centuries, Muslim astronomers – heirs to much older schools of astronomical science in Mesopotamia and Iran, Greece and Syria, India and Egypt – developed detailed astral tables (*zij*) for specific locations within the Islamic realm; their works also included instruction on how to determine local time by way of computers such as the astrolabe, the quadrant, the sextant, sundial theory and blueprints for the design of latitude-specific sundials. Al-Biruni dedicated a lengthy and important study to both the scripturalist and the scientific definitions of prayer times. This is his book on shadows (*The Exhaustive Treatise on Shadows* [*Ifrad al-maqal fi amr al-zilal*], which he completed in 1022; translation and commentary by E S. Kennedy, published by the Institute for the History of Arabic Science in Aleppo, 1976). In this work Abu al-Rayhan al-Biruni lays out some of the areas of ‘service’ that science is rendering to religion to benefit the community of the faithful as a whole and every individual believer within it. These include determination of the proper times and the proper direction of the five daily prayers (which requires knowledge of astronomy and geometry/trigonometry), computations of the beginning and end of the 12 lunar months of the Islamic year to aid in the process of crescent-sighting testimony as legislated in the sharia (which requires knowledge of astronomy and geometry/trigonometry) and then also *zakat* percentages (obligatory almsgiving), inheritance shares and buying and selling on the market (regulations that require knowledge of arithmetic/algebra and even geometry).

In his book on shadows, al-Biruni quotes all of the Qur'anic and Hadith-based laws on prayer mentioned above. Then he adds science on how best to implement these laws of the Qur'an and Hadith: not by following the ‘guesswork of observation’, but by relying on the hard data of higher mathematics. Important in the calculation of communal prayer times and other ritual obligations is a precise definition of locale. Here al-Biruni's text dwells at some considerable length on how to employ the data of local observations to determine the degree of local latitude and calculate the local meridian, because these are the coordinates on which the scientific prayer-time technology rests. Yet it is quite remarkable and significant that the astronomer al-Biruni should also take cognisance of such items as the old ‘time-stick’ technology. By reason of his own background, he was deeply interested in Sunni prayer-time traditions and their differences, but also maintained an ecumenical interest in other calendars. In the *Treatise on Shadows*, he recorded the prayer times as defined by the four Sunni schools of law (*madhahib*), the ‘Shi‘ites of Islam’, the Jews (three prayers per day), the

Christians (seven prayers per day), the Manicheans (where the number of prayers depends on the level of initiation) and the Magians/Zoroastrians (three daily prayers or more).

A scripturalist puzzle in al-Biruni's analysis of the Qur'an's many exhortations to prayer is the directive to pray 'the middle prayer' (Sura 2:238: 'observe the prayers and the middle prayer, and stand before God devoutly'). This had been a contested issue for many centuries. Al-Biruni reports that 'they disagree concerning it, and they explain it in so many ways, some of them attain the limit of the ridiculous'.

The traditionalist Abd Allah ibn Umar opined that the noon prayer (*zuhr*) was itself the 'middle prayer'. Conversely – according to al-Biruni – there seemed to be some consensus that the noon prayer was the 'first prayer'. This would make the sunset prayer (*maghrib*) the 'middle prayer', but only a minority of traditionalists supported this identification. A larger number of early scholars opined that the dawn prayer (*fajr*) is the 'middle prayer', by itself already special in that it cannot be 'paired' with another prayer (when prayer times are extended and merge). To al-Biruni, the correct answer to this puzzle was to identify the afternoon prayer (*'asr*) as the 'middle prayer', since it occurs between two daytime and two nighttime prayers; it is also special in that its time requires specific observation and calculation – unlike the prayers of dawn, midday, sunset and night, whose times are all writ in the sky.

In al-Biruni's time, the shadow stick represented the 'norm' of how prayer times were generally ascertained. This old technology led al-Biruni to contemplate the nature of light and shadow and how – in time-stick technology – each aids to define events that occur in the other:

> The signs of the prayer are [to be determined from] the effects of their opposites at their times. I mean that the reference for the two day-time prayers is the shadow, and the shadow belongs to the night, even though the sun is the indicator for it. The references for the nocturnal prayers are dawn and twilight, which appertain to the day because of the light.

The average *mu'adhdhin* (caller to prayer) at a local mosque most likely continued to calculate the local prayer times by way of traditional methods. Chosen for piety, moral standing and (at least *theoretically*) quality of voice, he would have memorized the prayer-time rules of his community's juridic school and, using mnemonic devices, known how to apply them on the basis of a rudimentary knowledge of folk astronomy that included observation of shadow lengths and lunar mansions.

Al-Biruni took a dim view of the 'guesswork' of ordinary *mu'adhdhins* who were incapable even of determining the arc of daylight (meridian line) at a specific place. Prerequisites for local time measurement were knowledge of astronomy and geometry – including knowledge of conic sections, 'which some call, because of their difficulty, spiritual geometry' – without which hourglasses and water clocks (on a cloudy day) were useless. In describing the relation of locality (latitude) to solar position (inclination of the ecliptic) in terms of combinations of trigonomic functions, al-Biruni emphasized that the mathematics and science in these calculations required knowledge of the ancient authorities (such as Archimedes and Euclid, Apollonius and Ptolemy), and he insisted that if a *mu'adhdhin* was unable or unwilling to study these sources, then he should swiftly relinquish his position to a more qualified candidate:

> So, if the muezzin is interested in deep investigation, and he abstains from [blind] imitation, and [if] his temperament is akin to the science of Ptolemy, and Archimedes, and Apollonius, and he never puffs himself up above these names, and he seeks schooling and education until he reaches this position, then verily he must take up the whole of the Book of the Elements [of Euclid] and the middle works between it and the Almagest [of Ptolemy], and he must give [himself over] to eight treatises of it. Thus he came as empty as the devil, but he goes away as victorious as [the prophet] Enoch [*Idris*]. If it happens that he becomes fed up from the very first with studying what we have mentioned, then let him take the shortest distance away from the work, let him shorten the length of hope by giving the bow over to one who can draw it and surrendering the matter to the experts who do not loathe steady striving for the reform of these elements and their improvements, and the production of their results to those who seek them.

Some *mu'adhdhins* of al-Biruni's acquaintance were experienced professionals who, after correctly determining the noon prayer period for their location, therefrom also correctly deduced the time of

the afternoon prayer for each day of the (solar) year. Other *mu'adhdhins* were of 'excessive ignorance'. One of them was upset that all the required solar measurement devices and timetables were based on the (solar) 'Byzantine year' and therefore useless for the (lunar) Islamic calendar, so he smashed the instrument that al-Biruni had used as a tool in his instruction. This is how al-Biruni describes this incident:

> [Unlike the scientifically inclined *mu'ezzins*], the other of the two parties are of the common people, whose hearts are disgusted by the mention of shadows, or altitude, or sines, and who get goose-pimples at the [mere] sight of computation and [scientific] instruments. With them it reaches such an extent that one cannot trust them with anything of the sort, much less the times of prayer, not because of unfaithfulness or treason, but because of excessive ignorance.
>
> … One of them sought my advice, and impelled me, because of his great ignorance of his profession, and my being afraid that he will make a mistake in the rules of my religion, to save him from guesswork by the use of an instrument for [determining] the times of the two prayers of the day according to the doctrine which he held. I showed him the Byzantine months, substituting [them] for the names of the signs. Then he began to suggest [about it] that it should be made according to the Arab months. So I stated to him that the matter has nothing to do with them, and in addition to being very confusing they would require intercalation, which is forbidden in Islam and very heretical. But his ignorance made him at the end refuse to accept anything based on the Byzantine months, not allowing it into the mosque, since [those] people are not Muslims. Then I said to him: 'The Byzantines also eat food and walk around in the market. Do not imitate them in these two things.' And, when explanation and instruction were useless, I confronted him, after all the stupidity, with [the fact of] his disease for which there is no cure, then I saw [him] forsake the reckoning by breaking that instrument.

Al-Biruni reserved his most sarcastic contempt for those who believe in the flatness of the earth and the parallelism of vertical (lines), which belongs in confused information

> to the extent that some of them are of the opinion that the time of noon is the same in all inhabited places. Thus they base themselves on false premises, which entail as a result their deviating in prayer away from the true direction.

By the thirteenth century, professional astronomers had begun to serve in the capacity of *muwaqqits* (regulators of prayer times) at prominent mosques in the metropolises of the Islamic world, and there were also astronomers with the epithet of *miqati* who specialised in spherical astronomy and astronomical timekeeping but were not necessarily associated with any religious institution. This large crowd of accomplished scientists left a rich legacy of sophisticated tables for time reckoning and regulation of prayer times; in the words of David King, these indicate close collaboration between the cadres of Islamic science and religion in premodern times. The fact is of interest in the ongoing debate about the nature of the Islamic *turath* (heritage), presented in Chapter 3, in that it contradicts nineteenth- and early-twentieth-century Orientalist readings of premodern Islamic culture that stipulated a drastic separation of religion and science in medieval Islam, followed by the early demise of science because of 'Islamic orthodoxy's' negative position toward the sciences.

Global Time and its Limits

It seems that both the ancient Egyptians and the ancient Babylonians used the seasonal rising of specific stars to divide their night and day into 12 hours of equal duration. The story of how these systems developed is quite complicated; in addition, it appears that both cultures also used seasonal hours and were able to convert one into the other by way of astronomical data. Other cultures defined their days' hours in different terms. But even in ancient Sumer, India, China and elsewhere, the number of hours reflected a shared tendency to use subdivisions that were multiples of 12 or 30, perhaps in analogy to the number of lunations in the astronomical year (approximately 12) and the days in a lunation (about 30).

Astronomers needed a less culture-specific and much more precise basis of time definition; in the second century BCE, the Hellenistic astronomer Hipparchus developed the notion of 'equinoctial hours',

based on the length of the hour at the two solar equinoxes, when the day is as long as the night. This scheme provided the astronomers with 24 subsections of the day that were of equal duration, independent of the seasons. Three hundred years later, Hipparchus's intellectual heir Ptolemy developed the concept further by dividing each equinoctial hour into 60 minutes. The 60 may have come to him from the sexagesimal system favoured by the ancient Babylonians. This system also underlay the many further measurements and calculations of Muslim astronomers and mathematicians. But both in the Middle East and in Europe, the astronomers' hours had little impact on how societies at large were measuring their time. Sundials, the astrolabe and, eventually, the quadrant and sextant were their main timepieces, while the hourglass (or, more rarely, a water clock) provided the means of measuring non seasonal time for special occasions.

There is, of course, a rich literature on how 'non seasonal/absolute' time was calculated in premodern Islamic history. At present I have only one second hand piece of political information and one second hand piece of farmer's practise and lore to contribute to the debate. The first is a communication from my colleague Heinz Grotzfeld (University of Münster) who in 2004 wrote that in an Egyptian chronicle of the early seventeenth century, he had come across a time unit called *daraja* ('degree'), meaning 4 minutes, which was an old concept in astronomy where 1° out of 360° represents four minutes of the daily 24-hour solar motion. In this chronicle, time periods spent in audience with the Sultan were recorded in terms of multiple *darajat*, but the source, who was a professional *wazzan* (member of the office of weights and measures), did not clarify by what technical means these time frames were established at the court on which he reported. My second example is about how the principle of the water clock to measure 'absolute' time underlay a device used by farmers in Upper Egypt to define the length of their labour in the fields. My Egyptian colleague Mamoun Fandy (University of London, School of Oriental and African Studies, or SOAS), who was born and grew up in Gurna, Luxor, told me that the farmers in his village used to time their turns at ploughing or harvesting by way of a tin can with a hole in it that was filled with water up to a specific level marked on the can's surface; each man then worked his shift until the water had dripped out and the can was dry.

The 12 unequal, 'temporal' or seasonal, hours of day and night prevailed in Europe even after the mechanical clock had been developed in England by the fourteenth century. Over time, this new technology spread across Europe in the form of public clocks that chimed the hour from churches and civic edifices; as these new mechanical timepieces could not keep track of seasonally fluctuating hours requiring constant adjustment, it was by way of the mechanical clock that the astronomers' equinoctial hour eventually came to replace seasonal time. It took the Europeans several centuries to perfect this system's mechanics and several more to coordinate time measurements across regions. While European coach travel in the eighteenth century could still get by on 'local' (solar) time, by the mid-nineteenth century the electrical telegraph and the railway required regional time coordination. This, in turn, required both calculation of *longitudes* – since two locales longitudinally separated even by a modest distance used different solar time settings – and the definition of *time zones* within which all the clocks of a predetermined number of longitudes would show the same time. By 1847 British railways used Greenwich mean time for all timetables, and in 1880 Greenwich mean time was made the legal, standard time in Great Britain.

Longitudes

Ancient science had developed both notions, longitudes and time zones. Hellenistic scientists and their predecessors charted astronomical and geographical data on the Earth's map in longitudes, imaginary lines that cover the globe in same-size circles, stretching far apart at the equator and converging at the poles. Longitudes are determined by observing and calculating the sun's passing through its zenith (high-noon position) in a North–South, pole-to-pole direction. Each line represents a meridian, an imaginary, vertical and semicircular disk above the earth. *A.m.* is ante-meridian time (meaning before high noon), and *p.m.* is post-meridian time (meaning after midday). Even though their cosmology stipulated a stationary Earth that neither spun around itself nor rotated around the sun, the meridians of longitude of the ancient scientists were the same as our own. So also was the notion of reckoning the earth's circumference in terms of 360° and to stipulate 24 time zones determined by 24 meridians spread at global intervals of 15°, 12° east and 12° west of a 'prime meridian' or 0° longitude line. But (unlike with latitudes) there were no compelling astronomical reasons to choose a specific longitude for the 0° position, since any line drawn from pole to pole could serve as a starting line for reference. The Hellenistic astronomer Ptolemy, working in Alexandria, Egypt, chose to locate 'his' prime

meridian close to home by running it through the Fortunate Islands (now called the Canary and Madeira Islands) off the north western coast of Africa. Later mapmakers moved 'theirs' to many other places, which had nothing to do with astronomy and everything to do with politics.

In her superb study titled *Longitude*, Dava Sobel explains that the measurement of longitude meridians is 'tempered by time'. To determine one's longitude in uncharted territory, especially at sea, one needs to know the precise time at one's locality, and also at another place of known longitude, at the very same moment. The time difference can then be converted into geographic separation. The world over, every hour of time difference means a distance of 15° of longitude. Since the world is a globe, this corresponds to a vastly larger geographical expanse at the equator than at higher latitudes on either side of the equator (and it shrinks to almost nothing at the poles). Sobel then tells the dramatic story of the British watchmaker John Harrison (d. 1776), who solved the problem of how sailors on the open sea could determine their boat's longitudinal position. After it had proven impracticable to employ astronomical observation, John Harrison constructed several truly reliable clocks that, set to London time, enabled British sailors to calculate their longitude by the time difference between time measured at their ship's location and London time:

> With the marine clocks, John Harrison tested the waters of space-time. He succeeded, against all odds, in using the fourth – temporal – dimension to link points on the three-dimensional globe. He wrested the world's whereabouts from the stars, and locked the secret in a pocket watch.

The eventual fixation of the prime meridian, or 0° longitude, in Greenwich (London) had started even before Harrison's mechanical solution was officially recognized and rewarded. It was the Greenwich Observatory's astronomer royal Nevil Maskelyne (d. 1811) who brought the meridian to Greenwich when he serially published his calculations of lunar distances (for use on land and water) in his *Nautical Almanac* and made the Greenwich meridian their reference point. International treaties concluded in 1883 and 1884 made the practise into law (even though the French held out until 1911) and also ratified the establishment of international time zones.

Time Zones

Over the past century and a third, 24 global time zones have each encompassed the area of 7.5° of longitude on either side of its centrally located meridian, whose local time determines the official time for all places within its zone. Their imaginary borders were modified when they cut through densely populated areas, in order to keep the smaller nations within a single time zone. In this system, the international date line, where today and tomorrow come together, runs roughly along the 180° meridian, with some deviations. On either side of this line, the time of day is the same, because the official meridian is always in the middle of a time zone; all that changes is whether one thinks of the present day as a Tuesday or a Wednesday. Crossing the line from East to West, a day is lost; crossing the line from West to East, a day is gained. The idea of a date line had been discussed, by those who knew that the world was round, for centuries on end. But Magellan's crew was still perplexed when they reached Cape Verde in 1522 on a Wednesday and the local inhabitants told them that this was their Thursday. On 2 July 2006, the *Washington Post* reported that in 1892, King Malietoa moved the international date line so that his country would be in accordance with the American, rather than the Australian, date. Because of this, the people of Samoa were treated to Monday 4 July, twice.

The international agreements on time zones, concluded well over a century ago, were a major step in the globalization process that we sometimes, wrongly, attribute to just our own time and technology. The electronic data of today's stock exchanges, politics, news coverages, flight monitors and weather maps have a long history behind them. Scores of generations of astronomers, geographers, mathematicians, sailors, explorers and all stripes of travellers have helped to lay the groundwork. Their knowledge has been globally traded between civilizations, because these have always drawn from one another in a competitive, spontaneous and mostly undesigned process. As if over a series of common thresholds, civilizations have unevenly stepped into new realms of technological innovation and control that profoundly affected their culture. The last two of those thresholds, the Industrial and the Electronic Revolutions, were designed and championed by the West. Yet it is a dangerously simplistic – a 'fundamentalist' – misreading of facts to designate their adoption by modernizing states and societies simply as processes of a desired 'Westernization'.

With technological progress came further chronographic and calendrical standardization that

eventually took on global validity. The Islamic prayer times are now regionally computed (often by electronic means), and the results are publicised by way of radio, television, newspapers, almanacs, wall and pocket calendars and now the internet. The computation is usually done by local survey departments or observatories or other agencies approved by the religious authorities, which generally means the Ministry of Awqaf (Charitable Endowments) or its equivalent. Prayer times are defined in terms of time-zone-specific, standardized time. Religious officials in the provinces usually know how to adjust the timetables issued for their country's major cities to allow for differences in terms of degrees of longitude as well as latitude.

Technology has also created the concept of linear time, a relatively recent Western invention that is replacing, or is poised to replace, the multiple, subjective and situation-specific times of the past. A precondition to this shift (as well as a potent symbol of our present-day, technology-induced global age) may very well be what has happened and is happening to 'time' in various cultures around the globe, whether by chronography, where the Western calendar often provides a global point of reference even if an indigenous calendar continues to be the official one, or by clock-based time, which is producing a new global psychology equating time with punctuality, efficiency and economic rationality. Modernization has given rise to partial use of double (or even triple) calendars, much less often to double timekeeping, but perhaps more generally to a spirit of 'temporal' utilitarianism. There is no doubt that most Arab businesses are now run on the principle of 'time equals efficiency'. Yet on the broader issue of how to 'reform' and 'modernize' social mores in the world of Islam, it is noteworthy that prominent theologians are participating in a modernization discourse on how to use the concept of time to advocate greater social order and enhance virtues such as punctuality and regularity, reliability and exactness.

An example is a recent publication by the 'global mufti', Sheikh Yusuf al-Qaradawi (now based in Qatar), who combines the ulama credentials of a doctoral degree from al-Azhar University in Cairo with those of early membership in the Egyptian branch of the Muslim Brotherhood. For well over 50 years, his publications and sermons, television shows and organizational activities, now also his electronic fatwas and web pages have profoundly influenced Muslim thinking on social and political, economic and cultural issues. In his book *Time in the Life of the Muslim* (*Al-waqt fi hayat al-Muslim* [fourth printing, 2004]), the sheikh employs the Qur'anic concept of time as God's gift to humankind; the human is responsible for how he uses it and will be judged accordingly on Resurrection Day. Time is man's most precious possession. The believer must preserve, save and spend it with the greatest care. 'Killing' time is a form of slow suicide, since he who 'kills' time – by playing backgammon or chess or cards and the like – is actually killing himself. Like health, leisure is one of God's great gifts to mankind, but leisure is also a danger in that it always 'fills up', most often with foolish schemes for the men and lustful, sensuous ones for the women. Therefore, the righteous forefathers (*al-Salaf al-Salih*, the first two or three generations of believers) always hated it when someone was idle. Today's Muslim must perform all required and scheduled activities, religious as well as worldly, punctually, efficiently and according to the proper time frame – not at 'any time' but at 'the proper time'. Time management is part of a righteous Muslim's way of life; this includes rising at dawn (or, at the latest, sunrise), going to bed at an early hour, eating one's big meal in the middle of the day and eating only a light supper at night.

While al-Qaradawi's model may perhaps appear to sound some parallels to the 'Protestant work ethic' of the West, his model is squarely based on aspects of the Qur'an's teaching about the nature and use of 'human time', and the sheikh's exhortations – far from being a call for Westernization – appertain to his blueprint for the only possible, culturally and legally indigenous modernization of Muslim societies. Like many others before and during his time, al-Qaradawi has declared that modernization is and must be an inner-Islamic affair, but one that carries global relevance. This indigenous, Islamically authentic modernization will take a different course from the West, which pursued its own modernity by way of secularization, but Western-developed technology can, and should, be harnessed to it.

Time (Still)… 'Sticks'

Measurement and management of time are cultural constructs. And older notions of time measurement can 'stick around' for a long time. In the Arab-Islamic world today, the Western calendar provides a global point of reference even where the Islamic year reigns supreme. More important to

the smooth workings of global enterprise is the now universal adoption of 24 global time zones whose standardized 24-hour increments are measured by clocks that, in each time zone, begin to tick off the new day at midnight. Although this may be ‘official time’, many Yemenis still refer to it as *Rumi* (originally meaning ‘Roman’, or ‘Byzantine’, now used in the sense of ‘Western’) time and refer to their indigenous system as ‘Arab’ time. Since in Yemen the ‘Arab day’ begins at about 6 p.m. of ‘Western’ time, a traditional Yemeni who says ‘see you Friday evening’ means a period commencing at 6 p.m. on Thursday. By this reckoning, the ‘Western’ hour of 6 a.m. on Friday is 12 p.m. ‘Arab’ time, and Friday's 12 noon is 6 p.m. ‘Arab’ time (and then the new day [Saturday] starts again with 12:00 a.m. ‘Arab’ time at about 6:00 p.m. on Friday).

In traditional communities in Saudi Arabia, the old system has likewise survived and created a system of double timekeeping. *Tawqit zawali* (meridian timekeeping) stands for time reckoning in which the hours are counted from noon and midnight (like in the West), while in *tawqit ghurubi* (sunset timekeeping), they are counted from the hour closest to sundown. In regions of the Najd (north central Saudi Arabia), sundown is seasonally pegged at 7 p.m. of ‘standard/meridian’ time. An Egyptian colleague of mine, Mamoun Fandy, described a visit of his to the house of a Saudi religious notable in the provincial town of Burayda in the Najd. In the imam's *majlis* room, on the traditional *wijar* (shelf for keeping coffeepots), were two clocks. One measured the time in the new ‘official’ way, by *zawali* (meridian) time, while the other clock was set on his region's *tawqit ghurubi*, where sunset represents 12 o'clock. My colleague noted that their visit began at 5:40 according to one of the clocks and at 10:40 according to the other. It made perfect sense. Their meeting occurred 1 hour and 20 minutes before the sunset hour that was pegged at 7 p.m. of ‘standard/meridian’ time.

This imam's mechanical clocks followed what had been long-standing practise in both Europe and the Middle East. Prior to the standardization of time measurement in the nineteenth century, the French and Germans began their equal-hour day at midnight; the English, Italians, Bohemians and Welsh also calculated their day in equal hours, but their zero hour was at sunset; and in Siena the zero hour was half an hour before sunset. There was also the ‘Babylonian’ and the ‘Greek’ model that calculated a day's beginning from sunrise, except that (as in the city of Nuremberg) the ‘Babylonian’ and the ‘Italian’ systems were sometimes combined. (On some Venetian clocks, the position of high noon is marked by the Roman numeral XVIII [18] to indicate the day's beginning at sunset, not midnight.) All clocks had to be recalibrated every five to ten days, and each parish or town published a set of tables indicating on which days and by how much the clocks had to be reset.

After the import of the European mechanical clock from the West, in many parts of the Islamic world the practise of using mechanical clocks to measure ‘Islamic time’ was the norm rather than the exception. Throughout the Ottoman Empire, clocks had long been owned and operated in private households and some public spaces, such as mosques. As related in a recent study by Mehmet Bengu Uluengin, for the Ottomans the ‘new day’ began every evening at sundown, when they set the clock dial at 12 (a.m.). The clock would run until the next sunset, when it was reset at 12 to mark the next day's beginning. For centuries, this system permitted Ottoman society to combine traditional daily life regulated by religious notions of time with the abstract, mathematical hours of the mechanical clock. Eventually, the Ottoman central administration abolished the old system because it had become an obstacle to modernization, but it was relinquished only reluctantly, at least by the public. Measurement and management of time are cultural constructs. But older notions of time measurement can ‘stick around’ for a long time.

‘What then is time? I know what it is if no one asks me what it is; but if I want to explain it to someone who has asked me, I find that I do not know.’ These words were written by Saint Augustine, bishop of Hippo, North Africa (d. 430), when he was exploring the mystery of God's creation of time out of eternity and his own mystery as a reflection of the mystery of God. Time to Saint Augustine's theology was something that could be measured but existed independently of celestial motions since, in fact, it was time that measured solar motion.

The Qur'an’s vision of time is likewise God centred. Time is God's creation. There can be no abstract time because God, ruler of the universe who is beyond time, is lord over time from the beginning to the end of Creation. While time is a function of God's omnipotence, so is its measurement a divine gift that God created for the benefit of mankind. The Qur'an presents richly designed examples that prove God's authorship of all celestial movements and their utility to the human race as devices to measure (but not to control) time. Night and day and even the 12 lunar months of the year are ‘appointed times for the [believing] people’. Reading the sky for the prayers of the day and for the 12 months of

the year is a constant reminder of God's divine power and Providence.

Sources Used and Suggestions for Further Reading

Abbott, Nabia, 'Appendix: Jundi Shahpur: A preliminary historical sketch', *Ars Orientalis* vii (1968), pp. 71–3.

Abdallahy, Reza, et al., 'Calendars', in Ehsan Shater (ed.), *Encyclopaedia Iranica*, Vol. 4, pp. 658–77 (New York: Routledge and Kegan Paul, 1990).

Adam, Barbara, 'Perceptions of time', in T. Ingold (ed.), *Companion Encyclopedia of Anthropology: Humanity, Culture and Social Life*, pp. 503–27 (London: Routledge, 1994).

—— *Time* (Cambridge: Polity Press, 2004).

—— *Time Watch: The Social Analysis of Time* (Cambridge: Polity Press, 1995).

Adamson, Peter, *Al-Kindi* (New York: Oxford University Press, 2007).

Ahmed, Monzur, *Moon Calculator, Version 6.0*, released 10 October 2001 (http://www.starlight.demon.co.uk.moncalc and http://www.ummah.org.uk/ildl/mooncalc.html).

Akbar, Moghul Emperor, *Mukatabat-i-Allami (Insha'i Abu al-Fazl) Dafter I: Letters of the Emperor Akbar in English Translation*, edited with commentary, perspective and notes by Mansura Haidar (New Delhi: Indian Council of Historical Research, 1998).

Albin, Michael W., 'Recent studies in Middle Eastern printing: A review essay', *Libraries and Culture*, xxiii/3 (1988), pp. 365–73.

Allen, Roger, *An Introduction to Arabic Literature* (Cambridge: Cambridge University Press, 2000).

Anawati, Georges, 'Science', in P. M. Holt, Ann K. S. Lambton and Bernard Lewis (eds), *The Cambridge History of Islam*, Vol. 2, pp. 741–79 (Cambridge: Cambridge University Press, 1970).

Anawati, Georges, et al., 'Al-Biruni, Abu Rayhan', in Ehsan Yarshater (ed.), *Encyclopaedia Iranica*, Vol. 4, pp. 274–87 (New York: Routledge and Kegan Paul, 1990).

Aro, Jussi, 'Encounter of cultures in the work of al-Biruni', in Hakim Muhammad Said (ed.), *Al-Biruni Commemorative Volume*, pp. 319–28 (Karachi: Time Press, 1979).

Ascher, Marcia, *Mathematics Elsewhere: An Exploration of Ideas Across Cultures* (Princeton: Princeton University Press, 2002).

Augustine, Saint, *The Confessions of Saint Augustine*, translated by Rex Warner (New York: New American Library of World Literature, 1963).

Aveni, Anthony, *Empires of Time: Calendars, Clocks and Cultures*, rev. ed. (Boulder: University Press of Colorado, 2002).

Ayoub, Mahmoud, *Redemptive Suffering in Islam* (The Hague: Mouton, 1978).

Balland, Daniel, et al., 'Calendars', in Ehsan Shater (ed.), *Encyclopaedia Iranica*, Vol. 4, pp. 658–77 (New York: Routledge and Kegan Paul, 1990).

Balslev, Anindita Niyogi, *A Study of Time in Indian Philosophy* (Wiesbaden: Otto Harrassowitz, 1983).

——, 'Time and the Hindu experience', in A. N. Balslev and J. N. Mohanty (eds), *Religion and Time*, pp. 163–81 (Leiden: Brill, 1993).

Bar-Asher, Meir M., 'Shiism and the Qur'an', in Jane D. McAuliffe (ed.), *Encyclopaedia of the Qur'an*, Vol. 4, pp. 593–603 (Leiden: Brill, 2004).

al-Biruni, Abu Rayhan Muhammad ibn Ahmad, *Alberuni's India: An Account of the Religion, Philosophy, Literature, Geography, Chronology, Astronomy, Customs, Law and Astrology of India about 1030*, translated and edited with notes and indices by Edward C. Sachau, Vols. 1–2 (1910; reprint, New Delhi: Oriental Books Reprint Corporation, 1983).

—— *Chronologie Orientalischer Volker von Alberuni*, edited by C. Edward Sachau (Leipzig: F. A. Brockhaus/Otto Harrassowitz, 1923).

—— *The Chronology of Ancient Nations*, an English version of the Arabic text of the *Athar-ul-Bakiya of Albiruni*, translated and edited with notes and index, by C. Edward Sachau (1879; reprint, London: Nachdruck Frankfurt: Minerva, 1969).

—— *The Determination of the Coordinates of Positions for the Correct Distances between Cities*, a translation from the Arabic *Kitab Tahdid Nihayat al-Amakin li-Tashih Masafat al-Masakin*, translated

by Jamil Ali (Beirut: American University of Beirut, 1967).

—— *The Exhaustive Treatise of Shadows*, a translation from the Arabic *Ifrad al-Maqal fi Amr al-Zilal*, translation and commentary by E. S. Kennedy, 2 vols. (Aleppo: Aleppo University Institute for the History of Arabic Science, 1976).

—— *Kitab al-Saydana fi'l Tibb*, edited and with an introduction and notes by Abbas Zaryab (Tehran: Iran University Press, 1991).

Blair, Sheila S., 'Writing and writing materials', in Jane D. McAuliffe (ed.), *Encyclopaedia of the Quran*, Vol. 5, pp. 558–59 (Leiden: Brill, 2006).

Blois, François de, et al., 'Biruni, Abu Rayhan', in Ehsan Yarshater (ed.), *Encyclopaedia Iranica*, Vol. 4, pp. 274–87 (New York: Routledge and Kegan Paul, 1990).

Bloom, Jonathan M., *Paper before Print: The History and Impact of Paper in the Islamic World* (New Haven: Yale University Press, 2001).

Bluedorn, A. C., *The Human Organization of Time: Temporal Realities and Experience* (Stanford: Stanford University Press, 2003).

Borst, A., *The Ordering of Time: From the Ancient Computus to the Modern Computer*, translated by A. Winnard (Cambridge: Polity Publishers, 1993).

Bosworth, Clifford Edmund, *The Ghaznavids* (Edinburgh: Edinburgh University Press, 1963).

Bosworth, Clifford Edmund, et al., 'Al-Biruni, Abu Rayhan', in Ehsan Yarshater (ed.), *Encyclopaedia Iranica*, Vol. 4, pp. 274–87 (New York: Routledge and Kegan Paul, 1990).

Bowering, Gerhard, 'Prayer', in Jane D. McAuliffe (ed.), *Encyclopaedia of the Qur'an*, Vol. 4, pp. 214–31 (Leiden: Brill, 2006).

—— 'Time', in Jane D. McAuliffe (ed.), *Encyclopaedia of the Qur'an*, Vol. 5, pp. 278–90 (Leiden: Brill, 2006).

Boyce, Mary, *A Persian Stronghold of Zoroastrianism* (Oxford: Oxford University Press, 1977).

Brand, Stewart, *The Clock of the Long Now: Time and Responsibility* (London: Phoenix, 2000).

Brezina, Corona, *Al-Khwarizmi: The Inventor of Algebra* (New York: Rosen, 2006).

Brown, Lloyd A., *The Story of Maps* (New York: Bonanza Books, 1949).

Bucaille, Maurice, *The Bible, the Qur'an and Science*, translated by Alastair D. Pannell and the author (Delhi: Taj, 1986).

Buddhue, John D., 'The origin of our numerals', *Scientific Monthly* lii/3 (1941), pp. 265–7.

al-Bukhari, Muhammad ibn Isma'il, *Sahih al-Bukhari*, in nine parts, 2 vols. (Cairo: Matabi' al-Sha'b, 1378).

—— *The Translation of the Meanings of Sahih al-Bukhari, Arabic-English*, translated by Muhammad Muhsin Khan, 9 vols. (Riyadh: Darussalam, 1997).

Bunt, Gary R., *Muslims: Rewiring the House of Islam* (Chapel Hill: University of North Carolina Press, 2001).

—— *Virtually Islamic: Computer-Mediated Communication and Cyber Islamic Environments* (Cardiff: University of Wales Press, 2000).

Byron, Robert, *The Road to Oxiana* (1937; reprint, Oxford: Oxford University Press, 2007).

Castells, M., *The Rise of the Network Society* (Oxford: Blackwell, 1996).

Chaucer, Geoffrey, *The Canterbury Tales*, an illustrated selection rendered into modern English by Nevill Coghill (New York: Penguin Books, 1977).

—— *A Treatise on the Astrolabe*, edited by Sigmund Eisner, Variorum Edition, Vol. 6 (Norman: University of Oklahoma Press, 2002).

Christoff, Mirena, 'Tardjama', in *Encyclopaedia of Islam*, 2nd ed., Vol. 12, pp. 788–90 (Leiden: Brill, 2004).

Cohn, Norman, 'Medieval millenarianism: Its bearing on the comparative study of millenarian movements', in Charles B. Strozier and Michael Flynn (eds), *The Year 2000* (New York: New York University Press, 1997).

Collins, G. W., 'Standard time: Time zones and daylight saving time', in S. L. Macey (ed.), *Encyclopedia of Time*, pp. 575–77 (New York: Garland, 1994).

Cook, David, 'The apocalyptic year 200/815–16', in Albert Baumgarten (ed.), *Apocalyptic Time*, pp. 41–68 (Leiden: Brill, 2000).

—— ‘Messianism and astronomical events during the first four centuries of Islam’, *Revue du Monde Musulman et de la Mediterranee* 91–94 (2000), pp. 29–51.

—— ‘Moral apocalyptic in Islam’, *Studia Islamica* 86 (1997), pp. 37–69.

—— ‘Muslim fears of the year 2000’, *Middle East Quarterly* 5 (June 1998), pp. 51–68.

Cook, Michael, *A Brief History of the Human Race* (New York: W. W. Norton, 2003).

Covington, Richard, ‘Arabic science: Lines of transmission’, *Saudi Aramco World* lviii/3 (2007), pp. 10–11.

—— ‘The astrolabe: A user's guide’, *Saudi Aramco World* lviii/3 (2007), pp. 22–3.

—— ‘Rediscovering Arabic science’, *Saudi Aramco World* lviii/3 (2007), pp. 2–9, 12–16.

—— ‘The third dimension’, *Saudi Aramco World* lviii/3 (2007), pp. 17–21.

al-Daffa', Ali Abdullah, *The Muslim Contribution to Mathematics* (London: Croom Helm, 1978).

Dallal, Ahmad, ‘Calendar’, in Jane D. McAuliffe (ed.), *Encyclopaedia of the Qur'an*, Vol. 1, pp. 272–73 (Leiden: Brill, 2001).

—— ‘Day and night’, in Jane D. McAuliffe (ed.), *Encyclopaedia of the Qur'an*, Vol. 1, pp. 497–98 (Leiden: Brill, 2001).

—— ‘Ibn al-Haytham's universal solution for finding the direction of the *qibla* by calculation’, *Arabic Sciences and Philosophy* 5 (1995), pp. 145–93.

—— *Islam, Science and the Challenge of History* (New Haven: Yale University Press, 2010).

—— ‘Islamic paradigms for the relationship between science and religion’, in Ted Peters, Muzaffar Iqbal and Syed Nomanul Haq (eds), *God, Life and the Cosmos*, pp. 197–222 (Aldershot: Ashgate, 2002).

—— ‘Science, medicine and technology: The making of a scientific culture’, in John L. Esposito (ed.), *The Oxford History of Islam*, pp. 155–213 (New York: Oxford University Press, 1999).

—— ‘Science and the Qur'an’, in Jane D. McAuliffe (ed.), *Encyclopaedia of the Qur'an*, Vol. 4, pp. 540–58 (Leiden: Brill, 2004).

Dani, Ahmad Hasan, ‘Al-Biruni's indica: A re-evaluation’, in Hakim Muohammed Said (ed.), *Al-Biruni Commemorative Volume*, pp. 182–9 (Karachi: Time Press, 1979).

Dantzig, Tobias, *Number: The Language of Science*, edited by Joseph Mazur (New York: Penguin, 2007).

Denbigh, K. G., *Three Concepts of Time* (New York: Springer Verlag, 1981).

Dimirdash, Ahmad Sa'id, *Al-Biruni, Abu al-Rihan Muhammad ibn Ahmad* (Cairo: Dar al-Ma'arif, 1980).

Dohrn-van Rossum, Gerhard, *History of the Hour: Clocks and Modern Temporal Orders*, translated by Thomas Dunlap (Chicago: University of Chicago Press, 1996).

Downing, Michael, *Spring Forward: The Annual Madness of Daylight Saving Time* (n.p.: Shoemaker and Hoard, 2005).

Duncan, David Ewing, *The Calendar* (London: Fourth Estate, 1999).

Dunn, Ross E., *The Adventures of Ibn Battuta* (Berkeley and Los Angeles: University of California Press, 1986).

Eickelman, Dale F., ‘Social sciences and the Qur'an’, in Jane D. McAuliffe (ed.), *Encyclopaedia of the Qur'an*, Vol. 5, pp. 65–75 (Leiden: Brill, 2006).

Eliade, M., *The Myth of the Eternal Return: Cosmos and History* (1949; reprint, London: Arkana, 1989).

—— *The Sacred and the Profane* (New York: Harcourt, Brace and World, 1959).

Elias, N., *Time: An Essay* (Oxford: Blackwell, 1992).

Elmquist, Karl Erik, ‘An observation on Chaucer's astrolabe’, *Modern Language Notes* lvi/7 (1941), pp. 530–4.

Elmusa, Sharif S., ‘Faust without the devil? The interplay of technology and culture in Saudi Arabia’, *Middle East Journal* v/3 (1997), pp. 345–57.

Embree, Ainslee T., ‘Foreign interpreters of India: The case of al-Biruni’, in Peter J. Chelkowski (ed.), *The Scholar and the Saint*, pp. 1–16 (New York: New York University Press, 1975).

Evans, James, *The History and Practice of Ancient Astronomy* (New York: Oxford University Press, 1998).

Fagg, L., *The Becoming of Time* (Atlanta: Scholars Press, 1995).

Fiqh Council of North America, ‘Fatwa on astronomical calculations’, *Islamic Horizons* (September–

October 2006).

Firestone, Reuven, 'Shakhinah', in Jane D. McAuliffe (ed.), *Encyclopaedia of the Qur'an*, Vol. 4, pp. 589–91 (Leiden: Brill, 2004).

Fischer, August, '"Tag und Nacht" im Arabischen und die semitische tagesberechnung', in *Abhandlungen der Philologisch-Historischen Klasse der Koniglichen Sachsischen Gesellschaft der Wissenschaften*, Vol. 27, no. 21, pp. 741–58 (Leipzig: B. G. Teubner, 1909).

Fleischer, Cornell, *Bureaucrat and Intellectual in the Ottoman Empire: The Historian Mustafa Ali* (Princeton: Princeton University Press, 1986).

Fraser, J. T., *Time, the Familiar Stranger* (Amherst: University of Massachusetts Press, 1987).

Freeman-Grenville, G. S. P., *The Muslim and Christian Calendars Being Tables for the Conversion of Muslim and Christian Dates from the Hijra to the Year A. D. 2000* (Oxford: Oxford University Press, 1963).

Freitag, Ulrike, 'Notions of time in Arab-Islamic historiography', *Storia della Storiografia* xxviii (1995), pp. 55–68.

Gandz, Solomon, 'Did the Arabs know the Abacus?', *American Mathematical Monthly* xxxiv/6 (1927), pp. 308–16.

—— 'The origin of the Ghubar numerals, or the Arabian abacus and the articuli', *Isis* xvi/2 (1931), pp. 393–424.

Gell, A., *The Anthropology of Time: Cultural Constructions of Temporal Maps and Images* (Oxford: Berg, 1992).

Gohlman, William E., *The Life of Ibn Sina: A Critical Edition and Annotated Translation* (Albany: State University of New York Press, 1974).

Goldziher, Ignaz, 'The attitude of orthodox Islam toward the "Ancient Sciences"', translated by Merlin L. Swartz, in *Studies on Islam*, pp. 185–215 (New York: Oxford University Press, 1981).

—— *Vorlesungen uber den Islam* (Heidelberg: Carl Winter's Universitatsbuchhandlung, 1925).

Goodman, Lenn E., *Avicenna* (London: Routledge, 1992).

—— 'Time in Islam', in A. N. Balslev and J. N. Mohanty (eds), *Religion and Time*, pp. 138–62 (Leiden: Brill, 1993).

Gordon, Stewart, *When Asia Was the World* (Boulder: Da Capo Press, 2008).

Greenberg, Ilan, 'When a kleptocratic, megalomaniacal dictator goes bad', *New York Times Magazine*, 5 January 2003, pp. 34–37.

Griffiths, Jay, *A Sideways Look at Time* (New York: Tarcher/Penguin, 2004).

Grundler, Beatrice, 'Sheets', in Jane D. McAuliffe (ed.), *The Encyclopaedia of the Qur'an*, Vol. 4, pp. 587–9 (Leiden: Brill, 2004).

Guillaume, A., *The Life of Muhammad: A Translation of Ibn Ishaq's Sirat Rasul Allah* (Oxford: Oxford University Press, 2001).

Gunther, Sebastian, 'Day, times of', in Jane D. McAuliffe (ed.), *Encyclopaedia of the Qur'an*, Vol. 1, pp. 499–504 (Leiden: Brill, 2001).

—— 'Tag und tageszeiten im Qur'an', *Erlesenes: Hallesche Beitrage zur Orientwissenschaft* xxv/98 (1998).

Gutas, Dimitri, *Avicenna and the Aristotelian Tradition: An Introduction to Reading Avicenna's Philosophical Works* (Leiden: Brill, 1998).

—— *Greek Thought, Arabic Culture: The Graeco-Arabic Translation Movement in Baghdad and Early Abbasid Society (2nd–4th/8th–10th Centuries)* (London: Routledge, 1998).

—— et al., 'Tardjama', in *Encyclopaedia of Islam*, 2nd ed., Vol. 10, pp. 225–31 (Leiden: Brill, 1998).

Haber, Francis C., *The Age of the World: Moses to Darwin* (Westport, Conn.: Greenwood Press, 1978).

Hamad, Muhammad Abd al-Hamid, *Hayat al-Biruni* (Damascus: al-Mada, 2000).

Hashmi, Moulana Abdul Quddus, 'Ka'aba episode: A historical perspective', *Islamic Order* i/4 (1979), pp. 7–8.

Heck, Paul, 'Politics and the Qur'an', in Jane D. McAuliffe (ed.), *Encyclopaedia of the Qur'an*, Vol. 4, pp. 125–51 (Leiden: Brill, 2004).

Heydari-Malayeri, M. (Paris Observatory), 'A concise review of the Iranian calender' (http:// aramis.obspm.fr/ heydari/divers/ir-cal-eng.html).

The Holy Bible Containing the Old and New Testaments (New York: American Bible Society, n.d.).

The Holy Qur'an, Arabic and English as translated by Abdullah Yusuf Ali (Washington: Islamic Center, 1978).

Hopkins, T. J., *The Hindu Religious Tradition* (Belmont: Dickenson, 1971).

Hourani, Albert, *Arabic Thought in the Liberal Age, 1789–1939* (Cambridge: Cambridge University Press, 1983).

—— *A History of the Arab Peoples* (New York: Warner Books, 1991).

Hubert, Henri, *Essay on Time: A Brief Study of the Representation of Time in Religion and Magic*, translated by Robert Parkin and Jacqueline Reading (Oxford: Durkheim Press, 1999).

Hussain, Jassim M., 'Messianism and the Mahdi', in Seyyed Hossein Nasr, Hamid Dabashi and Seyyed Vali Reza Nasr (eds), *Expectations of the Millennium: Shi'ism in History*, pp. 14–22 (Albany: State University of New York Press, 1989).

Ibn Battuta, *Travels in Asia and Africa*, translated and selected by H. A. R. Gibb (London: Routledge and Kegan Paul, 1929).

Ibn Sina, 'Al-Biruni correspondence', translated by Rafik Berjak and Muzaffar Iqbal, *Islam and Science* i/1 (2003), pp. 91–8; i/2 (2003), pp. 253–60; ii/1 (2004), pp. 57–62; ii/2 (2004), pp. 181–87; iii/1 (2005), pp. 57–62; iii/2 (2005), pp. 166–70; iv/2 (2006), pp. 165–72.

Ikuko, Nishimoto, 'The "civilization" of time: Japan and the adoption of the Western time system', *Time and Society* vi/2–3 (1997), pp. 237–60.

Ionides, S. A., 'Description of an astrolabe', *Geographical Journal* xxiv/4 (1904), pp. 411–17.

Iqbal, Muzaffar, *Islam and Science* (Burlington: Ashgate, 2002).

Iranian calendar (http://en.wikipedia.org/wiki/Persian_calendar).

Jacques, E., *The Form of Time*, (London: Heinemann, 1982).

Jordanian Astronomical Society, 'The actual Saudi dating system' (http://www.jas.org.jo/sau.html).

Kamiar, M., *A Bio-bibliography for Biruni Abu Raihan Mohammad Ibn Ahmad (973–1053 C. E.)* (Lanham: Scarecrow Press, 2006).

Kaptein, Nico I. G., 'Seasons', in Jane D. McAuliffe (ed.), *Encyclopaedia of the Qur'an*, Vol. 4, pp. 571–72 (Leiden: Brill, 2004).

Kechichian, Joseph A., 'The ulama in Saudi politics', *International Journal of Middle East Studies* xviii/1 (1986), pp. 53–71.

Kennedy, Edward S., *Astronomy and Astrology in the Medieval Islamic World* (Brookfield: Ashgate, 1998).

—— 'Al-Biruni, Abu Rayhan ibn Ahmad', in Charles Coulston Gillispie, Hans Berger and Christoph Buys Ballot (eds), *Dictionary of Scientific Biography*, Vol. 2, pp. 142–58 (New York: Charles Scribner's Sons, 1970).

—— 'Al-Biruni on the Muslim times of prayer', in Peter J. Chelkowski (ed.), *The Scholar and the Saint*, pp. 83–94 (New York: New York University Press, 1975),

—— 'Al-Biruni's Mas'udic Canon' (1971), reprinted in David A. King and Mary Helen Kennedy (eds), *Studies in the Islamic Exact Sciences by E. S. Kennedy, Colleagues and Former Students*, pp. 573–95 (Beirut: American University of Beirut, 1983).

—— *A Commentary upon Biruni's Kitab Tahdid al-Amakin, an 11th Century Treatise in Mathematical Geography* (Beirut: American University of Beirut, 1973).

—— 'A history of trigonometry', *31st Yearbook, National Council of Teachers of Mathematics* (1969), pp. 333–59.

—— 'Mathematical geography', in Roshdi Rashed (ed.), *Encyclopedia of the History of Arabic Science*, Vol. 1, pp. 185–201 (London: Routledge, 1996).

Kennedy, Hugh, *The Armies of the Caliphs: Military and Society in the Early Islamic State* (London: Routledge, 2001).

—— *When Baghdad Ruled the Muslim World: The Rise and Fall of Islam's Greatest Dynasty* (Boulder: Da Capo Press, 2005).

Khalidi, Tarif, *Classical Arab Islam* (Princeton: Darwin Press, 1985).

Khan, Aisha, *Avicenna (Ibn Sina): Muslim Physician and Philosopher of the Eleventh Century* (New York: Rosen, 2006).

Kimber, Richard, 'Qibla', in Jane D. McAuliffe (ed.), *Encyclopaedia of the Qur'an*, Vol. 4, pp. 325–28 (Leiden: Brill, 2004).

King, David A., 'Applications of folk astronomy and mathematical astronomy to aspects of Muslim ritual', *Arabist* xiii–xiv (1995), pp. 251–74.

—— 'Astrolabes, quadrants and calculating devices', in Gudrun Kramer, Denis Matringe, John Nawas and Everett Rowson (eds), *Encyclopaedia of Islam*, Vol. 3 (Leiden: Brill, 2008).

—— 'Astronomy and Islamic society: Qibla, gnomonics and timekeeping', in Rushdi Rashed (ed.), *Encyclopaedia of the History of Arabic Science*, Vol. 1, pp. 128–84 (London: Routledge, 1996).

—— *Astronomy in the Service of Islam* (Aldershot and Brookfield: Ashgate/Variorum, 1993).

—— 'From inscriptions to context: Some Islamic astronomical instruments and their secrets', in Irene A. Bierman (ed.), *Text and Context in Islamic Societies*, pp. 87–130 (Reading: Garnet, 2004).

—— *Islamic Astronomical Instruments* (London: Variorum Reprints, 1987).

—— *Islamic Mathematical Astronomy*, 2nd ed. (1986; reprint, Aldershot and Brookfield: Variorum, 1993).

—— *Al-Khwarizmi and New Trends in Mathematical Astronomy in the Ninth Century*, Hagop Kevorkian Center for Near Eastern Studies, Occasional Papers on the Near East, no. 2 (New York: New York University Press, 1983).

—— 'Kibla: Sacred direction', in *Encyclopaedia of Islam*, 2nd ed., Vol. 5, pp. 83–88 (Leiden: Brill, 1991).

—— 'Mikat: Astronomical timekeeping', in *Encyclopaedia of Islam*, 2nd ed., Vol. 7, pp. 26–31 (Leiden: Brill, 1991).

—— 'The orientation of medieval Islamic religious architecture and cities', *Journal for the History of Astronomy* xvi (1995), pp. 253–74.

—— 'The sacred direction of Islam: A study in the interaction of religion and science in the Middle Ages', *Interdisciplinary Science Review* X (1985), pp. 315–28.

—— 'A survey of medieval Islamic shadow schemes for simple time reckoning', *Oriens* 32 (1990), pp. 191–249.

—— *World Maps for Finding the Direction and Distance to Mecca: Innovation and Tradition in Islamic Science* (London: al-Furqan Islamic Heritage Foundation and Brill, 1999).

Klein, Wolfgang Wassilios, *Abu Reyhan al-Biruni und die Religionen. Eine interkulturelle Perspective*, Interkulturelle Bibliothek Band 119 (Nordhausen: Traugott Bautz, 2005).

Knysh, Alexander, 'Months', in Jane D. McAuliffe (ed.), *Encyclopaedia of Islam*, Vol. 3, pp. 409–14 (Leiden: Brill, 2003).

Lacey, Robert, and Danny Danziger, *The Year 1000* (Boston: Little, Brown, 2000).

Landes, David S., *Revolution in Time: Clocks and the Making of the Modern World* (Cambridge: Belknap Press of Harvard University Press, 1983).

Landes, Richard, 'The apocalyptic year 1000', in Charles B. Strozier and Michael Flynn (eds), *The Year 2000* (New York: New York University Press, 1997).

—— 'The fear of an apocalyptic year 1000: Augustinian historiography, medieval and modern', *Speculum* lxxv/1 (2000), pp. 97–145.

—— 'Lest the millennium be fulfilled: Apocalyptic expectations and the pattern of Western chronography, 100-800 C. E.', in Werner Verbeke, Daniel Verhelst and Andries Welkenhuysen (eds), *The Use and Abuse of Eschatology in the Middle Ages* (Leuven: Leuven University Press, 1988).

—— *Relics, Apocalypse and the Deceits of History: Ademar of Chabannes, 989–1034* (Cambridge: Harvard University Press, 1995).

Latham, Maria, 'The astrolabe', *American Mathematical Monthly* xxiv/4 (1917), pp. 162–8.

Lawrence, Bruce B., 'Biruni, Abu Rayhan', in Ehsan Yarshater (ed.), *Encyclopaedia Iranica*, Vol. 4, pp. 274–87 (New York: Routledge and Kegan Paul, 1990).

—— 'Comparative study of Indian culture', in Ehsan Yarshater (ed.), *Biruni Symposium*, pp. 27–47, Persian Studies no. 7 (New York: Columbia University Press, 1976).

—— 'The use of Hindu religious texts in al-Biruni's *India* with special references to Patanjali's Yoga-Sutras', in Peter J. Chelkowski (ed.), *The Scholar and the Saint*, pp. 29–48 (New York: New York University Press, 1975).

Lebling, Robert, 'Arabic in the sky', *Saudi Aramco World* LXI/5 (2010), pp. 24–33.

Leemhus, Frederik, ‘Apocalypse’, in Jane D. McAuliffe (ed.), *Encyclopaedia of the Qur'an*, Vol. 1, pp. 111–14 (Leiden: Brill, 2001).

Le Goff, J., *Time, Work and Culture in the Middle Ages* (Chicago: University of Chicago Press, 1980).

Lenz, Hans, *Universalgeschichte der Zeit* (Wiesbaden: Marix Verlag, 2005).

Levine, Robert, *A Geography of Time* (New York: Basic Books, 1997).

Lindberg, David C., *The Beginnings of Western Science* (Chicago: University of Chicago Press, 1992).

Lippincott, Kristen, with Umberto Eco, E. H. Gombrich and others (eds), *The Story of Time* (London: Merrell Holberton, 1999).

Livingstone, E. A., *Oxford Concise Dictionary of the Christian Church*, 2nd ed. (New York: Oxford University Press, 2000).

Macey, Samuel L., *The Dynamics of Progress: Time, Method and Measure* (Athens: University of Georgia Press, 1989).

—— (ed.), *Encyclopedia of Time* (New York: Garland, 1994).

Makki, Jum'a Muhammad, *Awqat al-Salawat al-Mafruda li-Ahl al-Rafahiyya wal-‘Udhr wal-Darura* (Cairo: Dar al-Huda, 1988).

Malik ibn Anas, *Al-Muwatta': The First Formulation of Islamic Law*, translated by Aisha Abdurrahman Bewley (Granada: Madinah Press, 1992).

Manchester, Peter, ‘Time in Christianity’, in Anindita Niyogi Balslev and J. N. Mohanty (eds), *Religion and Time*, pp. 109–37 (Leiden: Brill, 1993).

Marmura, Michael E., ‘Ghazali's attitude to the secular sciences and logic’, in George F. Hourani (ed.), *Essays in Islamic Philosophy and Science*, pp. 100–111 (Albany: State University of New York Press, 1975).

Mead, Jenna, ‘Geoffrey Chaucer's treatise on the astrolabe’, *Literature Compass* iii/5 (2006), pp. 973–91.

Monnot, G., ‘Salat’, in *The Encyclopaedia of Islam*, 2nd ed., Vol. 8, pp. 925–34 (Leiden: Brill, 1995).

Moosa, Ebrahim, ‘Shaykh Ahmad Shakir and the adoption of a scientifically based lunar calendar’, *Islamic Law and Society* v/1 (1998), pp. 57–89.

Morgan, Michael Hamilton, *Lost History: The Enduring Legacy of Muslim Scientists, Thinkers and Artists* (Washington, D. C.: National Geographic Society, 2007).

Morrison, James E., *The Astrolabe* (Tallmadge, Ohio: S. D. Myers, 2007).

Muhammad, Abd al-Ghani Abd al-Rahman, *Al-Zaman Bayna al-Dunya wal-Akhira* (Cairo: Madbuli, 1997).

Naqvi, Syed Sibte, ‘The evolution of cosmology in the hands of Muslims up to the time of al-Biruni’, in Hakim Mohammed Said (ed.), *Al-Biruni Commemorative Volume*, pp. 558–77 (Karachi: Times Press, 1979).

Nasr, Seyyed Hossein, ‘Al-Biruni as philosopher’, in Hakim Mohammed Said (ed.), *Al-Biruni Commemorative Volume*, pp. 400–6 (Karachi: Times Press, 1979).

—— *An Introduction to Islamic Cosmological Doctrines: Conceptions of Nature and Methods Used for Its Study by the Ikhwan al-Safa, al-Biruni and Ibn Sina* (Albany: State University of New York Press, 1993).

—— and M. Mohaghegh, *Questions and Answers (between Ibn Sina and Biruni)* (Kuala Lampur: International Institute for Islamic Thought and Civilization, 1995).

Nazim, Muhammad, *The Life and Times of Sultan Mahmud of Ghazna* (Cambridge: Cambridge University Press, 1931).

Neugebauer, Otto, *Astronomy and History: Selected Essays* (New York: Springer, 1983).

—— ‘The early history of the astrolabe’, Studies in Ancient Astronomy IX, *Isis* xl/3 (1949), pp. 240–56.

Neuwirth, Angelika, ‘Cosmology’, in Jane D. McAuliffe (ed.), *Encyclopaedia of the Qur'an*, Vol. 1, pp. 440–58 (Leiden: Brill, 2001).

—— ‘Ramadan’, in Jane D. McAuliffe (ed.), *Encyclopaedia of the Qur'an*, Vol. 4, pp. 338–48 (Leiden: Brill, 2004).

North, John D., ‘The astrolabe’, *Scientific American*, no. 230 (1974), pp. 96–106.

—— *The Fontana History of Astronomy and Cosmology* (London: Fontana Press, 1994).

Osborn, Marijane, *Time and the Astrolabe in the Canterbury Tales* (Norman: University of Oklahoma Press, 2002).

Panaino, Antonio, et al., 'Calendars', in Ehsan Yarshater (ed.), *Encyclopaedia Irania*, Vol. 4, pp. 658–77 (New York: Routledge and Kegan Paul, 1990).

Paret, Rudi, *Der Koran: Kommentar und Konkordanz*, 2nd ed. (Stuttgart: W. Kohlhammer, 1981).

Pedersen, Johannes, *The Arabic Book*, translated by Geoffrey French (Princeton: Princeton University Press, 1984).

Peters, F. E., *Muhammad and the Rise of Islam* (Albany: State University of New York Press, 1994).

—— 'Science, history and religion: Some reflections on the *India* of Abu Rayhan al-Biruni', in Peter J. Chelkowski (ed.), *The Scholar and the Saint*, pp. 17–27 (New York: New York University Press, 1975).

—— 'Science, history and religion: Some reflections on the *India* of Abu Rayhan al-Biruni', in Hakim Mohammed Said (ed.), *Al-Biruni Commemorative Volume*, pp. 233–42 (Karachi: Time Press, 1979).

Peterson, Daniel Carl, 'Creation', in Jane D. McAuliffe (ed.), *Encyclopaedia of the Qur'an*, Vol. 1, pp. 467–70 (Leiden: Brill, 2001).

Pinch, Geraldine, *Egyptian Mythology: A Guide to the Gods, Goddesses and Traditions of Ancient Egypt* (New York: Oxford University Press, 2002).

Pingree, David, et al., 'Al-Biruni, Abu Rayhan', in Ehsan Yarshater (ed.), *Encyclopaedia Iranica*, Vol. 4, pp. 274–87 (New York: Routledge and Kegan Paul, 1990).

—— 'Al-Biruni's knowledge of Sanskrit astronomical texts', in Peter J. Chelkowski (ed.), *The Scholar and the Saint*, pp. 67–81 (New York: New York University Press, 1975).

—— 'Brahmagupta', in Charles Coulston Gillispie (ed.), *Dictionary of Scientific Biography*, Vol. 2, pp. 416–18 (New York: Charles Scribner's Sons, 1970).

—— 'Al-Fazari, Muhammad ibn Ibrahim', in Charles Coulson Gillispie (ed.), *Dictionary of Scientific Biography*, Vol. 4, pp. 555–6 (New York: Charles Scribner's Sons, 1971).

Proclamation of the Birth of Christ, from the Roman Martyrology for Christmas Mass, 2005 (http://www.firstthingscom).

Ptolemy, Claudius, *Ptolemy's 'Almagest'*, translated by Gerald J. Toomar (1984), reprinted as *The Almagest by Ptolemy* (Princeton: Princeton University Press, 1998).

—— *Ptolemy: The Almagest*, translated by R. Catesby Taliaferro, in Mortimer J. Adler (ed.), *Great Books of the Western World*, pp. 1–480 (Chicago: University of Chicago Press, 1990).

al-Qaradawi, Yusuf, *Al-Waqt fi Hayat al-Muslim* (Cairo: Maktabat Wahba, 2004).

Rahman, Fazlur, 'The eternity of the world and the heavenly bodies in post-Avicennan philosophy', in George F. Hourani (ed.), *Essays in Islamic Philosophy and Science*, pp. 222–37 (Albany: State University of New York Press, 1975).

al-Razi, Fakhr al-Din Muhammad ibn Umar, *Al-Tafsir al-Kabir*, Vol. 13 (Cairo: al-Matba'a al-Bahiyya al-Misriyya, 1938).

Richards, E. G., *Mapping Time* (New York: Oxford University Press, 1994).

Rida, Rashid Muhammad, *Tafsir al-Manar*, 12 vols. (Beirut: Dar al-Ma'rifa, n.d.).

Robinson, Neal, 'Antichrist', in Jane D. McAuliffe (ed.), *Encyclopaedia of the Qur'an*, Vol. 1, pp. 107–11 (Leiden: Brill, 2001).

Rosenthal, Franz, 'Al-Biruni between Greece and India', in Ehsan Yarshater (ed.), *Biruni Symposium*, pp. 1–12, Persian Studies no. 7 (New York: Columbia University Press, 1976).

Russell, D. S., *The Method and Message of Jewish Apocalyptic* (Philadelphia: Westminster Press, 1964).

Russell, J. L., 'Time in Christian thought' (1966), in J. T. Fraser (ed.), *The Voices of Time*, pp. 59–76 (Amherst: University of Massachusetts Press, 1981).

Sachau, Edward C., *Alberuni's India* (1910; reprint, New Delhi: Kegan Paul, 1983).

Sachedina, Abdulaziz A., 'Messianism and the Mahdi', in Seyyed Hossein Nasr, Hamid Dabashi and Seyyed Vali Reza Nasr (eds), *Expectations of the Millennium: Shiism in History* (Albany: State University of New York Press, 1989).

Saidan, Ahmed, 'Al-Biruni on trigonometry', in Ekmeleddin Ihsanoglu and Feza Gunergun (eds), *Science in Islamic Civilization*, pp. 167–78 (Istanbul: Istanbul Research Centre for Islamic History, Art and Culture [IRCICA], 2000).

—— 'The trigonometry of al-Biruni', in Hakim Mohammed Said (ed.), *Al-Biruni Commemorative*

Volume, pp. 681–90 (Karachi: Times Press, 1979).

Saliba, George, *A History of Arabic Astronomy: Planetary Theories during the Golden Age of Islam* (New York: New York University Press, 1994).

—— 'Persian scientists in the Islamic world: Astronomy from Maragha to Samarqand', in Richard G. Hovannisian and Georges Sabagh (eds), *The Persian Presence in the Islamic World*, pp. 126–46 (Cambridge: Cambridge University Press, 1998).

—— 'Science and medicine: A review of the *Encyclopedia Iranica*', *Iranian Studies* xxxi/3-4 (1998), pp. 681–90.

—— et al., 'Al-Biruni, Abu Rayhan', in Ehsan Yarshater (ed.), *Encyclopaedia Iranica*, Vol. 4, pp. 274–87 (New York: Routledge and Kegan Paul, 1990).

Samuel, Alan E., *Greek and Roman Chronology: Calendars and Years in Classical Antiquity* (Munich: Beck'sche Verlagsbuchhandlung, 1972).

Sarton, George, *Ancient Science and Modern Civilization* (Lincoln: University of Nebraska Press, 1954).

Scheppler, Bill, *Al-Biruni: Master Astronomer and Muslim Scholar of the Eleventh Century* (New York: Rosen, 2006).

Schimmel, Annemarie, *I Am Wind, You Are Fire: The Life and Work of Rumi* (Boston: Shambhala, 1992).

—— *Die Zeichen Gottes: Die religiose Welt the Islam* (Munich: C. H. Beck, 1995).

Schmidtke, Sabine, 'Mu'tazila', in Jane D. McAuliffe (ed.), *Encyclopaedia of the Qur'an*, Vol. 3, pp. 466–71 (Leiden: Brill, 2003).

Scholler, Marco, 'Post-Enlightenment academic study of the Qur'an', in Jane D. McAuliffe (ed.), *Encyclopaedia of the Qur'an*, Vol. 4, pp. 187–208 (Leiden: Brill, 2004).

Seife, Charles, *Zero: The Biography of a Dangerous Idea* (New York: Penguin Books, 2000).

Serjeant, R. B., and David A. King, 'Isma'il al-Akwa', calendars, the time of day and mathematical astronomy', in R. B. Serjeant and Ronald Lewcock (eds), *San'a': An Arabian Islamic City*, pp. 32–35 (London: World of Islam Festival Trust, 1983).

—— and Ronald Lewcock (eds), *San'a': An Arabian Islamic City* (London: World of Islamic Festival Trust, 1983).

al-Shafi'i, Muhammad ibn Idris, *Kitab al-Umm*, Vol. 1 (Beirut: Dar al-Ma'rifa, 1973).

Shah, Zulfiqar Ali, 'Astronomical calculations', *Islamic Horizons* (September–October 2006), pp. 50–1.

Shamsi, F. A., 'Abu al-Raihan Muhammad ibn Ahmad al-Bayruni', in Hakim Mohammed Said (ed.), *Al-Biruni Commemorative Volume*, pp. 260–88 (Karachi: Time Press, 1979).

Sharot, Stephen, 'Jewish millenarianism: A comparison of medieval communities', *Comparative Studies in Society and History* xxii/3 (1980), pp. 394–415.

Shaukat, Khalid, 'Eid al-Adha with the Hajjis', *Islamic Horizons* (May–June 2002), p. 64.

—— 'Islamic calendar development in North America', *Islamic Horizons* (Eid 1418/1998), pp. 23–4.

—— 'Perfecting prayer times', *Islamic Horizons* (May–June 2001), p. 50.

Shimlavi, Hilal, 'One world Islamic calendar: A three-step program is helping to create a unified international Islamic calendar', *Islamic Horizons* (July–August 2000), p. 62.

Siraj Ed-Din, Abu Bakr, 'The Islamic and Christian conceptions of the march of time', *Islamic Quarterly* i/4 (1954), pp. 229–35.

Skovgaard-Petersen, Jacob, *Defining Islam for the Egyptian State* (Leiden: Brill, 1997).

Smith, David Eugene, and Salih Mourad, 'The dust numerals among the ancient Arabs', *American Mathematical Monthly* xxxiv/5 (1927), pp. 258–60.

Smith, Jane I., and Yvonne Y. Haddad, *The Islamic Understanding of Death and the Resurrection* (Albany: State University of New York Press, 1981).

Sobel, Dava, *Longitude: The True Story of the Lone Genius Who Solved the Greatest Scientific Problem of His Time* (New York: Penguin Books, 1995).

—— *The Planets* (New York: Viking Penguin, 2005).

—— 'The shadow knows: Why a leading expert on the history of timekeeping set out to create a sundial unlike anything the world has ever seen', *Smithsonian*, January 2007, pp. 88–95.

Starr, S. Frederick, 'Rediscovering Central Asia', *Wilson Quarterly* (Summer 2009), pp. 33–43.

Steensgaard, P., 'Time in Judaism', in Balslev Anindita Niyogi and J. N. Mohanty (eds), *Religion and*

Time, pp. 63–108 (Leiden: Brill, 1993).

Stone, Williard E., 'Abacists versus algorists', *Journal of Accounting Research* x/2 (1972), pp. 345–50.

Stowasser, Barbara Freyer, 'The end is near: Minor and major signs of the hour in Islamic texts and contexts', in Abbas Amanat and John J. Collins (eds), *Apocalypse and Violence*, pp. 45–67 (New Haven: Yale Center for International and Area Studies, 2004).

—— *A Time to Reap: Thoughts on Calendars and Millennialism* (Washington, D. C.: Center for Contemporary Arab Studies, Georgetown University, 2000).

—— *Women in the Qur'an, Traditions and Interpretation* (New York: Oxford University Press, 1994).

Taji-Farouki, Suha, 'Introduction', in Suha Taji-Farouki (ed.), *Modern Muslim Intellectuals and the Qur'an*, pp. 1–36 (New York: Oxford University Press, 2004).

Teresi, Dick, *Lost Discoveries* (New York: Simon and Schuster, 2002).

Theroux, Paul, 'The golden man: Saparmurat Niyazov's reign of insanity', *New Yorker*, 28 May 2007, pp. 55–65.

Tucker, Abigail, 'Invisible glory: Two unsung space telescopes create eye-opening images of the universe from light we can't see', *Smithsonian Magazine*, February 2011, pp. 75–9.

Tufail, Mohammed, 'Hindu society at the time of al-Biruni', in Hakim Mohammed Said (ed.), *Al-Biruni Commemorative Volume*, pp. 295–7 (Karachi: Times Press, 1979).

Tyson, Neil de Grasse, 'For the love of Hubble', *Washington Post Parade Magazine*, 22 June 2008, pp. 6–7.

Uluengin, Mehmet Bengu, 'Secularizing Anatolia tick by tick: Clock towers in the Ottoman Empire and the Turkish Republic', *International Journal of Middle East Studies* xlii/1 (2010), pp. 17–36.

Van Brummelen, Glen, *The Mathematics of the Heavens and the Earth: The Early History of Trigonometry* (Princeton: Princeton University Press, 2009).

Varisco, Daniel Martin, *Medieval Folk Astronomy and Agriculture in Arabia and the Yemen* (Aldershot and Brookfield: Ashgate, 1997).

—— 'Moon', in Jane D. McAuliffe (ed.), *Encyclopaedia of the Qur'an*, Vol. 3, pp. 414–16 (Leiden: Brill, 2003).

—— 'Numerology', in Jane D. McAuliffe (ed.), *Encyclopaedia of the Qur'an*, Vol. 3, pp. 554–5 (Leiden: Brill, 2003).

—— 'The origin of the *anwa'* in Arab tradition', *Studia Islamica*, no. 74 (1991), pp. 5–28.

Verde, Tom, 'Houses of wisdom', *Saudi Aramco World* lxi/3 (2010), pp. 24–37.

Von Grunebaum, G. E., 'The sources of Islamic civilization', in P. M. Holt, Ann K. S. Lambton and Bernard Lewis (eds), *The Cambridge History of Islam*, Vol. 2, pp. 469–510 (Cambridge: Cambridge University Press, 1970).

Watt, W. Montgomery, 'Al-Biruni and the study of non-Islamic religions', in Hakim Mohammed Said (ed.), *Al-Biruni Commemorative Volume*, pp. 414–19 (Karachi: Times Press, 1979).

—— 'The Muslim yearning for a saviour: Aspects of early Abbasid Shi'ism', in S. G. Brandon (ed.), *The Saviour God*, pp. 194–200 (Westport, Conn.: Greenwood Press, 1980).

—— and Richard Bell, *Introduction to the Qur'an* (1977; reprint, Edinburgh: Edinburgh University Press, 1990).

Weber, Eugene, *Apocalypses* (Cambridge: Harvard University Press, 1999).

Whitrow, G. J., *Time in History: The Evolution of Our General Awareness of Time and Temporal Perspective* (Oxford: Oxford University Press, 1988).

—— *What is Time?* (New York: Oxford University Press, 2003).

Wiedemann, Eilhard, 'Ein Instrument, das die Bewegung von Sonne und Mond darstellt, nach al-Biruni', *Der Islam* iv (1913), pp. 5–13.

Yarshater, Ehsan, 'The Persian presence in the Islamic world', in Richard Hovannisian and Georges Sabagh (eds), *The Persian Presence in the Islamic World*, pp. 4–125 (Cambridge: Cambridge University Press, 1998).

Young, Michael, *The Metronomic Society: Natural Rhythms and Human Timetables* (Cambridge: Harvard University Press, 1988).

Young, M. J. L., J. D. Latham and R. B. Serjeant (eds), *Religion, Learning and Science in the Abbasid Period* (Cambridge: Cambridge University Press, 1990).

Youssefi, G. H., ‘Abu Reyhan Biruni, a lover of truth’, in Ehsan Yarshater (ed.), *Biruni Symposium*, pp. 13–26, Persian Studies no. 7 (New York: Columbia University Press, 1976).

Zerubavel, E., *Hidden Rhythms: Schedules and Calendars in Social Life* (Chicago: University of Chicago Press, 1981).

—— *The Seven Day Cycle: The History and Meaning of the Week* (Chicago: University of Chicago Press, 1985).

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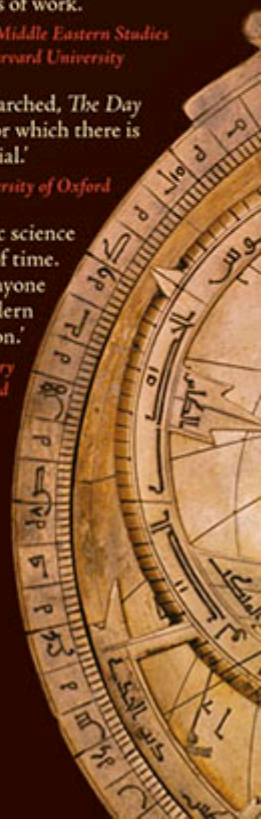

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